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A book

on

ASTRONOMY

(RELEVANT TO ASTROLOGY)

+ upagrahas

by

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Published by

Bharatiya Prachya Evam Sanatan Vigyan Sansthan

।। सूर्य मंत्र ।।

ॐ घृणिः सूर्य आदित्योम्।

इस मंत्र में सूर्य को तीन अलग-अलग नामों से याद किया गया है।

ज्योतिष के प्रकाण्ड विद्वान स्वामी विद्यारण्य जी, (जिन्हें हम मूर्खानन्द जी के नाम से जानते हैं) इस मंत्र का जाप ज्योतिष के विद्यार्थियों के लिए लाभकारी बताते थे।

Surya Mantra

In this Mantra, god Sun has been remembered by three different names.

(Swamy Vidyaranya Ji whom we all know by the name Swamy Moorkhananda Ji, used to recommend this Mantra as very beneficial to all students of astrology.)

CONTENTS

Introduction

The present book of astronomy has been written for students who want to learn Hindu Astrology and possess knowledge of mathematics up to the 10+2 standard and know the elements of plane geometry, algebra etc. Though the book contains the figures of three dimensions, yet the students can understand the astronomical concepts. Using their imaginations and graspping the points explained.

In writing this book, help has been taken from the class notes on Indian Astronomy by Shri R. N. Vashist (I.A.&A.S, Retd.), *Elements of Astronomy* by George W. Parker, *Spherical Astronomy* by W. M. Smart and *A to Z Astronomy* by Patric Moore.

I hope students will find these lessons useful for understanding astronomy and its utilisation in astrology.

The book is divided into eleven chapters for a smooth and easy grasp of the subject as under:

Chapter 1 — Astronomy and its Historical Background

Chapter 2 — Definitions

Chapter 3 and 4 — Earth and Solar System

CHAPTER 1

General

Astronomy is the science which deals with the heavenly bodies. Since the man saw the Sun, the Moon, Stars etc., he wanted to find out the reason behind them and how day and night, and seasons etc. occur. Thus started the astronomical concept in his mind. In prehistoric times, our ancestors gazed at the Sun, the Moon and other heavenly bodies in the sky and grouped the stars into constellations and rashis.

HISTORICAL BACKGROUND

Western

Historically speaking, we can divide western astronomical development, in three eras: ancient, medieval and modern.

Among the ancient astronomers mention should be made of the Greek geometer **Pythagorus** (562–500 BC), who was one of the first to maintain that the Earth was not flat. He made some study of the movement of planets known in his time. Next came **Heraclides** (388–315 BC), a Greek philosopher, who believed that the Earth rotated on its axis in a period of 24 hours. **Aristarchus** of Samos (310–250 BC) felt

that the Earth moves in an orbit round the Sun. He tried to measure the relative distances of the Moon and the Sun, though the results were inaccurate. Next came the real breakthrough when **Hipparchus** (190–120 BC) appears to have prepared a star catalogue. The original star catalogue of Hipparchus has not been preserved but it would be quite justified to say that **Ptolemy** based his star catalogue on that of Hipparchus, who also had discovered the precession of equinoxes and had even ventured to quantify it by saying that its rate cannot be less than 36" of an arc per year. The last and really important astronomer of the classical times was **Claudius Ptolemy** (AD 120–180) of Alexandria. His book *Almagest* has come down to us through an Arab translation. This book gives a gist of the ancient scientific knowledge. Ptolemy left a star catalogue and data on the motion of planets and stars. There was an eclipse in Greek astronomy after him. Their tradition was continued for more than 1000 years by the Arabs in a subdued form.

Among the astronomers of medieval time the first landmark is by **Nicholas Copernicus** (AD 1473–1543) who stipulated that the Sun is the centre of the solar system and planets move around the Sun. He was a Polish astronomer and his book was released on his death in AD 1543. The next important astronomer was **Galileo** (AD 1564–1642) who was an experimental telescope observer. His championship of Copernicus theory resulted in his persecution by the state and the church. A mention also must be made of the Danish astronomer **Tycho Brahe** (AD 1564–1601), an expert observer astronomer of the pre-telescope era. He compiled a star catalogue and made observations on planets. **Kepler** (AD 1571–1630) used Brahe's data

to show that planets move round the Sun in **elliptical orbits** whose one focus is the Sun.

He also enunciated the three Kepler's laws of planetary motion. **Sir Issac Newton** (AD 1642–1727) enunciated his famous laws of motion and built the first reflector–type telescope, called after him '**Newtonian**'. During this very period, lived the Danzig astronomer named **Johann Havetius** (AD 1611–1667), who had his observatory at Danzig (in Poland). He compiled a map of moon and is known for his notable star catalogue. During this very (seventeenth) century, another notable observer astronomer **Christian Huygens** (1629-1695), a Dutch scientist made his contribution by recognizing, for the first time, the nature of Saturn's rings. Mention has also to be made of the famous royal (British) astronomer **Edmond Hailey** (AD 1656–1742) who was not only instrumental in publication of Newton's book *The Principia* in 1687, but he also predicted the return of a famous **Comet** (Hailey's Comet) many times observed in the past and observed by Hailey in 1672 and after 76 years in 1758 (Its latest return was in 1986.) - also return in 1835, 1911 (earliest seen in 2467 BC).

The modern era should be counted from partly eighteenth century (after Newton), nineteenth century and the current twentieth century. This is marked by building up of many observations, bigger telescopes with more signification and resolution and a large number of astronomers, British, German, French, American etc.

In the nineteenth century, spectroscopy and photography were developed which made radical

changes in experimental and observational fields. From about 1870 large refractors were built (telescopes with lenses). With the development of photography, human eye was mostly replaced by recorded photographs. During the twentieth century, larger reflectors (mirrors) superseded the refractor. Radio astronomy made its first appearance in 1930. With the advent of space age in 1957, astronomical observations are made from artificial satellites or by landing of space craft (e.g. on Moon, Venus, Mars etc.). Use was also made of infra-red, X-rays, gamma rays which were absorbed in atmosphere. Astro-physics and astrospectroscopy based on analysis of frequencies of light received from star lead to many important results regarding content material of a particular star and its recession, velocity etc.

The name of a few astronomers of this period are mentioned below:

(1) **Sir William Herschel** (1738–1821) A great German observer born in 1781, he discovered the planet Uranus (also called Herschel). He also discovered thousands of new double stars, clusters and nebulae. He gave an idea of the shape of the Galaxy. His largest reflector telescope had a 49-inch mirror. His sister Caroline and his son Sir John (1792-1871) were also astronomers of repute.

(2) **Francis Bailey** (1774–1894) An English astronomer who is remembered for his observations of Bailey's beads (brilliant points seen along the edge of Moon's disc) at the time of solar eclipse.

(3) **Francois Arago** (1786–1853) was director of

Paris observatory. He devoted himself to many studies of the Sun.

(4) **F. W. August Argelander** (AD 1799–1875) was a German astronomer. He produced important star catalogues.

(5) **Sir George Bidell Airy** (AD 1861-1892) The British astronomer royal (7th) was responsible to raise Greenwich observatory (in England) to a position of eminence, and contributed to astronomy and time-keeping.

(6) **Johann Galle** (AD 1812–1910) was the German astronomer, who along with H.L.D. Arrest, discovered the planet. Neptune in 1846. Le Verrier (AD 1811–1877), French astronomer and mathematician's calculations led to this discovery.

(7) **John Couch Adams** (AD 1819–1892) English mathematical astronomer made correct prediction of the planet Neptune.

(8) **Sir Norman Lockyer** (AD 1823–1920) was English astrophysicist and spectroscopist. He and Jansen (AD 1824–1907), French astronomer, independently of each other, discovered the method of observing solar prominences (other than at the time of total solar eclipse).

(9) **Asaph Hall** (AD 1829–1907) American astronomer. His discovery of Phobos and Deimos (in 1877) the two satellites of Mars.

(10) **Sir David Gill** (AD 1843–1914) was a Scotish astronomer. He was a pioneer in photographic mapping of the sky.

(11) **Robert Aitken** (AD 1864-1949) was an American astronomer. Director of Lick Observatory (California, 120-inch reflector telescope) and 36-inch refractor (largest in that category, completed in 1888). Observer of double stars.

(12) **S. Walter Adams** (AD 1876–1936) was an American astronomer. He was director of Wilson Observatory. He did important work in Stellar spectroscopy.

(13) **George Eller Hale** (AD 1868–1938) was an American astronomer who set up great 200-inch (reflector) telescope at Palomear Observatory (completed in 1948), the largest telescope in the world for many years. He is also famous for inventing spectroheliograph.

(14) **Hanrietta Swan Leavitt** (AD 1888–1921) An American woman astronomer discovered 2,400 variable stars, four novae, several minor planets (asteroids). She discovered in 1912 the period luminosity law of Cepheids.

In the twentieth century, great research in astronomy took place also due to advent of space age, ever since Sputnik was launched by Russia in October 1957. There were Moon landings, and probes into Venus and Mars, Jupiter and Saturn. It would be difficult to mention so many astronomers, astrophysicists, astrospectroscopists, and space scientists. However, mention may be made of Clyde Tombangh (1907), great American astronomer, who discovered the planet Pluto (9th planet) in 1930, with systematic search from the Lavell observatory in Arizona.

Indian Astronomy

Now we must turn our attention to the origin and history of Indian astronomy. It is very ancient, it pertains to a period much earlier than those of the Greek philosophers and astronomers. It started well, had depth of knowledge, accurate mathematical calculations, a system of observations (but there were no telescopes etc.). But, after political subjugation of India, the result was burning of libraries and suppression of intellectual research. Hence, India lagged behind in experimental observation especially during the last three centuries.

In *Adi Ramayana* by Valmiki (contemporary of Rama's era), Dasrath talks of starting of his rahu maraka dasha. He is also and the consequent need of coronation of a successor. Then muni Vashishtha ('*kula purohit*') fixed Pushyami nakashatra as *muhurta* for coronation to take place. Since Rama's birth was mentioned as having taken place in Punarvasu Nakshatra in Karkat (cancer) lagna, Pushyami was considered auspicious being second from birth Rashi (nakshatra). Again, Ram-Ravana Yuddha was initiated on amavasya (considered good for starting a war) which ended on the 10th day of shukla paksha with Ravana *vadha*. Even till today, navaratra and vijaya dashami are celebrated starting from a particular amavasya.

Again, in *Mahabharata*, war was stipulated to start from amavasya. Krishna was described to have performed pitritarpan, a day earlier than starting of war (due to diference in Ayanamsha calculation).

We have the age-old tradition of astronomy and based on that of astrology. The two went hand in

glove. It was difficult to visualise an astrologer who was not an astronomer and vice versa. The two sciences were linked like body and soul. In *Bhagawat Purana,* the complete position of planets at the time of Lord Krishna's birth is given. In *Mahabharata,* Bhishma Pitamaha, the great patriarch of kauravas and pandavas, who had fallen in the battlefield, pierced with arrows shot by Arjuna, would not die till the sun becomes auspicious by being towards the north, *uttarayana* (i.e. after winter solstice) – around 22nd December.

All these incidents are ample to proof of existence of the deep study of the two divine sciences of astronomy and astrology, under *jyotish shastra,* the science dealing with jyoties, the lights, (lit planets and heavenly bodies).

In the ancient times, all shastras used to be studied intensively in ashramas of great gurus, rishis devoted to learning, who practised yogas and did Research. The guru used to teach in depth and the learning process was usually extended over decades. The truths were committed to heart and memory through *sutras* and aphorisms which were like condensed knowledge. There was no printing process. Granths were written in hand on natural material (leaves etc.) Hence we do not have any books of ancient times. Nevertheless, knowledge has passed to us through scholars over the ages.

Now what are the various source-shastras on astronomy and who are the scholars? Surya siddhanta is one of the oldest siddhantas on the subject which has come down to us from ages. Even Varahmihira wrote a commentary on surya

siddhanta. Regarding the age of Varahmihira, some fixed it as (AD 550) Varah also mentions in his Pancha Siddhantika Arya Bhatta– (AD 499). But some associate Varahmihira to the court of Vikramaditya of Ujjain. However, everyone knows that vikrami samvat starts from BC 57 (while saka era starts from AD 78).

Most of the Indian astronomical works are claimed as divine revelations to various sages. Some of these Siddhantas are mentioned:

1. Surya siddhanta
2. Paitamaha siddhanta
3. Vyasa siddhanta
4. Vashishtha siddhanta
5. Atri siddhanta
6. Parashara siddhanta
7. Kashyapa siddhanta
8. Narada siddhanta
9. Garga siddhanta
10. Marichi siddhanta
11. Manu siddhanta
12. Angira siddhanta
13. Lomasa siddhanta
14. Paulisa siddhanta
15. Chayavana siddhanta
16. Yavana siddhanta
17. Bhirgu siddhanta
18. Saunaka siddhanta

In the modern Sanskrit encyclopedia, the "ShabdaKalpa-Druma", a list of nine treatises entitled "Siddhanta" is given, which are: Brahma, Surya, Soma, Brihaspati, Garga, Narada, Parashara, Pulastya, Vashishtha siddhantas (S. No. 1, 4, 6, 8, and 9 are repetitions here). A lot of research is needed to establish their origin, era, actual authorship etc. However, in the present imprecise state of historical background, and pending further research, we can broadly classify these under the following four categories.

The first category clearly claims to be the

revelations and of very very antique origin and unknown authorship. In this category, we may name Brahma, Surya, Soma, Brihaspati and Narada siddhantas.

(a) **Surya siddhanta** is at the top of this class of revelations. Though it is of unknown ancient origin, its various translations and editions are available. It is stated to be revealed by Sun God to Asura Maya in **2163102 BC** (verses 2-9 of Surya siddhanta Chapter-1). Surya siddhanta has three stages: the original works as it existed before Varahmihira; Varaha's adaptation of it with the epicyclic theory being added to it; later adaptations and alterations. Its commentator Ranganatha (AD 1608) made it safe from further interpolations and this can be termed as modern Surya siddhanta whose various translations and commentaries are available.

(b) **Brahma siddhanta**, said to be part of "Vishnudharamatra Purana", which work itself appears to us to have lost, is said to be a revelation of Barhma to Narada.

(c) **Soma (Moon) siddhanta** follows the main system of Surya siddhanta. A manuscript of it was available in Berlin Library (Weber Catalogue No. 840).

(d) **Brihaspati siddhanta** is the revelation by Brihaspati, the guru of Gods. It is not available, but is referred to quite often as an authority in astronomical issues in many Hindu works on astronomy.

(e) **Narada Siddhanta**, is also not available. There are, however, occasional references to Narada as

an authority in astronomical works. However, *Narada Samhita* (a course on astrology) was available in Berlin Library (Weber Catalogue No. 862).

In the second category, we can list works attributed to ancient and renowned sages i.e. Garga, Parashara, Vyasa, Pulastya and Vashishtha (the last being member of the group of great seven rishis - Sapta Rishis-after whom a constellation is also named).

(a) **Garga siddhanta** is also not available. Only references to it are made in some other astronomical works.

(b) **Vyasa siddhanta** is also not available.

(c) **Parashara siddhanta.** Second chapter of Arya siddhanta contained an extract of this work. However, a work called *Vrihatta Prashara* (a work of system of astrology) is available in the Mackenzie collection (Wilson Catalogue (*i*) 120).

(d) **Pulastya siddhanta.** It is also not available; it is at times confused with Paulisa siddhanta (which school of Greek origin was a rival of Arya Bhatta).

(e) **Vashishtha siddhanta**. Its system corresponds with the Surya siddhanta. More than one treatise of this name is referred to by Colebrooks and Bentley. A later compilation by one Vishnu Chandra was founded partly upon this siddhanta and partly upon material from Arya-bhatta. Vrihatta Vashishtha siddhanta was in Mackenzie collection (Wilson Catalogue (*i*) 121).

In the third category, belonging to authors established in the later history, we may group

siddhantas of authors like Aryabhatta, Varahmihira, Brahm Gupta, Romaka Siddhanta.

(a) **Arya siddhanta**. Two principal works of Aryabhatta-I (AD 499) are - *Arya Ashataka-shata* (800 verses) and *Dasha Gitika* (10 cantos). Berlin Library had a copy (Weber Catalogue no. 834), a work which was a commentary on Dasha, Gitika. Bentley had two treatises called *Arya Siddhanta* and *Laghu-Arya-Siddhanta.*

(b) **Varaha siddhanta**. A great and known astronomical work of Varahmihira (AD 550) was *Panch-Siddhantika* (i.e. a compendium of 5 astronomical works) founded upon Brahma, Surya, Paulisa, Vashishtha and Ramaka siddhantas. It is no longer in existence; Vrahahamihira's astrological works are however available.

(c) **Brahma siddhanta**, of Brahm Gupta (AD 628). Its complete name is *Brahma-Sphuta-Siddhanta.* Colebrooke and Bentley had its copies. On it was founded Bhaskra's (AD 1150) *Siddhanta Shiromani. Khandakadhyaka* is another important work of Brahm Gupta.

(d) **Romaka siddhanta.** Colebrooke links it to an author Srisena. It is founded partly on Vashishta siddhanta. It has been cited by Varahmihira in his *Pancha Siddhantika.*

In the fourth category, we may put later texts of known time and authorship. These are not so original works, but are mostly compilations, adaptations, and commentaries based on earlier siddhantas.

(a) **Siddhanta Shiromani**, of Bhaskara Acharya of

twelfth century (AD 1150). It is founded upon Brahma siddhanta of Brahm Gupta (AD 628). It is cited very frequently. It is a very prominent work.

(b) **Bhoja siddhanta**. It was published during the reign of Raja Bhoja of Dhar in 10th-11th centuries.

(c) **Siddhanta sundara**. It was composed by Gnan Raja in the sixteenth century AD.

(d) **Graha-Laghav**. A much venerated treatise, it is a composition of Ganesha (AD 1520).

(e) **Siddhanta Tattva Viveka**. It was composed by Kamalakara (AD 1620).

(f) **Siddhanta sarbhauma**, authored by Munishavara (son of Ranganatha, commentator of Surya siddhanta).

(g) **Of the above**, modern publications are those of the Surya siddhanta of Ranganatha, the *Siddhanta Shiromani*, and *Graha Laghva*, and these should be available in the market with some effort. There are numerous other minor works of an era later than sixteenth century.

In the above historical discussion, some of the important astronomical scholars and writers could not be covered. A mention of those left over scholars must also be made briefly. These are:

NAME		WORK
Lata Deva (AD 505) (Pupil of Arayabhatta-I)	:	Expounder of Romaka and Paulisha siddhanta
Lalla (AD 748)	:	Sisya Adhivriddhida

NAME		WORK
Manjula (AD 932)	:	The Laghumanasa and the Brahma Manasa
Sripati (AD 1028)	:	The Siddhanta Sekhara

The basic astronomical time-frame used in Surya siddhanta is a *mahayuga*, which consists of 4 *yugas* - *satya* or *kritya*, *treta*, *dvapar* and *kaliyuga*. A *mahayuga* is fixed at 4,320,000 solar years and is divided in the four yugas in the proportion of 4:3:2:1, the *kaliyuga* being the shortest i.e. 432,000 years. This *mahayuga* has significant in so far as all planets and all nodes and epicycles of conjuctions complete their full revolution in this period (with no fractions left) and, hence, all will start afresh from their original positions.

From comparison of various astronomical constants, such as the number of planetary revolutions (including those of Moon's nodes) in a *mahayuga*, dimensions of Epicycles of Apsis, dimensions of Epicycles of conjuction (Sighra Epicycles), Geocentric orbitals etc., we observe that there was a Surya siddhanta even before Arya-bhatta-I (AD 499) who adopted the elements as they came down to him. However, these constants were changed in *Khandakadhayaka* (Brahm gupta), by Varahmihira, and in the modern Surya siddhanta at the beginning of the sixteenth century after making Bija corrections.

Number of revolutions of various planets and other crucial points, in a *Mahayuga* of 4,320,000 solar years, is given in the table on the next page.

S. No.	Planet	According to Khandak -adhyaka	According to Surya siddhanta of Varaha	According to Modern Surya siddhanta (Ranganatha's)	Number after Bija Correction
1.	Moon	57,753,336	57,753,336	57,753,336	57,753,336
2.	Sun	4,320,000	4,320,000	4,320,000	4,320,000
3.	Mars	2,296,824	2,296,824	2,296,832(+ 8)	2,296,832
4.	Jupiter	364,220	364,220	364,220	364,212 (– 8)
5.	Saturn	146,564	146,564	146,568(+ 4)	146,580(+ 12)
6.	Moon's Apogee	448,219	448,219	448,203(– 16)	448,199(– 4)
7.	Venus	7,002,388	7,022,338	7,022,376(– 12)	7,022,364(–12)
8.	Mercury	17,937,000	17,937,000	17,937,060(+ 60)	17,937,044(–16)
9.	Moon's Node	232,226	232,226	232,238(+ 12)	232,242(+ 4)

No. of civil days according to Khandakadhayaka

= 1577,917,800 days
(from Aryabhatta-I's *Ardharatrika*)

No. of civil days according to Varaha's Surya siddhanta

= 1577,917,800 days
(from Pancha Siddhantika)

No. of civil days according to modern scientist

= 1577,917,828 days

There were measurements and constants also for dimensions of epicycles of Apsis, of the 'sighra' Epicycles, Geocentric orbitals inclinations of planets. The Bija corrections were made at about the beginning of the fifteenth century (source Bentley).

Number of total revolutions of the asterisms (nakshatras) in a mahayuga is: 1,582,237,828 (Verse 34 of Chapter I of *Surya Siddhanta*). This gives us the

number of sidereal days in a *mahayuga*.

Thus from a comparison of astronomical constants we can say that Surya Siddhanta was in existence much before Varahamihira's time and he was one of the first to improve upon and update it.

The mean time of one sidereal revolution of the various planets in mean solar days according to modern Surya Siddhanta and with Bija correction is given below:

Planet	Time of Sidereal Revolution	
	In Mean Solar days	as Corrected by the Bija in Mean Solar Days
Sun	365.25875648	
Mercury	87.96970228	87.96978075
Venus	224.69856755	224.69895152
Mars	686.99749394	
Jupiter	4,332.32065235	4,332.41581277
Saturn	10,765.77307461	10,764.89171783
Moon Sidereal Rev.	27.32167416	
Synodic Rev.	29.53058795	
Apsis	3,232.09367415	3,232.12015592
Node (Rahu)	6,794.39983121	6,794.28280845

The number of oscillations of Equinoxes is fixed at 600 (due to precession of the Earth's axis) in 4,320,000 years, which means one complete oscillation is estimated to take 7,200 years. The Ayanamsa was zero at the beginning of *kaliyuga* and was again zero at AD 499 (the time of Aryabhatta-I) 421 Saka (or 3600 years reckoned from the beginning of *kaliyuga* 3102 BC). (Chapter III, verses 9 - 12). The

annual rate of precession (mean rate) works out to 54" of an arc per solar year.

Total number of years that are estimated to have elapsed since the beginning of creation up to AD 499 can be calculated as follows:

No. of years since creation to the end of the last *Kritayuga*	1953,720,000
No. of years of *Treta* and *Dwapar Yugas*	2,160,000
No. of *years* of *Kaliyuga* elapsed (up to AD 499)	3,600
Total	1955,883,600 (x)
No. of oscillations of Equinoxes (x/7200)	271,650½

In the mean position of an oscillation, Ayanamsa is zero. The circle of constellation was about to oscillate eastwards at AD 499 Surya siddhanta was thus revealed 2,163,600 years before Aryabhatta- I.

Most of the ancient Hindu scientific astronomy appears to be re-established in the era of Aryabhatta-I, as all calculations start from AD 499 according to Aryabhatta- I and the modern Surya siddhanta. Aryabhatta is also taken to be the father of Indian Epicyclic astronomy.

Now let us compare the times of revolutions for various planets as given in Indian classical works like Surya Siddhanta (as corrected from time to time, which corrections are not very substantive) with the periods as now known to western modern astronomers.

Planet	Distance (million miles)	Sidereal Period of a Revolution modern	Synodic Periodic (days)	According to Indian Sources
Mercury	36	86 days	115.9 days	87.97 days
Venus	67.2	224.7 days	583.9 days	224.7 days
Earth/Sun	92.957	365.3 days		365.26 days
Mars	141.5	687 days	779.9 days	687 days
Jupiter	483.3	11.9 years	398.9 years	4332 days
Saturn	886.1	29.5 years	378.1 days	10766 days
Uranus	1783	84.0 years	369.7 days	- (not given)
Neptune	2793	164.8 years	367.5 days	- (" ")
Pluto	3667	247.7 years	366.7 days	- (" ")
Moon	*distance from Earth (miles)*	*time of revolution*	*Synodical month*	*Sidereal time of rev. according to Indian Sources*
Perigee	221,460	27.32 days	29.53 days	27.32 days
Apogee	252,700			

If we compare with the periods of revolutions worked out by Aryabhatta-I, Varahmihira, Brahm Gupta and in the modern Surya Siddhanta (the difference between all corrections spread over a 1000 years being quite minor compared to the original), the difference with modern astronomical values of the same are found to be astonishingly small. It is a wonder how the ancient astronomers could work out these time periods so accurately without even having the advantage of modern powerful astronomical instruments and facilities.

Main points of difference between modern western astronomy and Indian classical astronomy

1. The Western astronomical calculations are heliocentric. Taking the Sun as stationary in the

solar system, all the planets are moving round it in somewhat Elliptic Orbits in time periods of their own. Of course, now the Sun is also taken as moving (along with the solar system) in our Galaxy (the milky way) and this Galaxy is also moving in space and the space itself is expanding outwards. The Indian classical system, on the other hand, is Geocentric with the observer (on the Earth) as the centre and all net (or compounded or resultant) motions of the planets (including the Sun, nodal and other points) being measured relative to the Earth.

2. The planets (as well as astronomical crucial points like Nodes, Equinox, the Apsis, and Mandochha, the Conjuction or the Shigrochha etc.) have all been alloted a number of revolutions in a *mahayuga* of 4,320,000 solar years. The mean period of a revolution is fixed only by dividing this (common time of a *mahayuga*) by the number of revolutions for each. The time is reckoned from the beginning of the Universe. No such absolute motion from time of the commencement of the Universe is followed in the western astronomy. Of course, the Universe is now stated to have originated in a split second, with a big bang (out of nothingness), about 20 billion years ago. How the two ideas correlate to each other is a matter for modern research.

3. The sidereal location of stars is fixed from zero degree of a fixed Aries (Ashivini) with a starry reference point at the end of Revati Nakshatra and the star Revati. In *chitra paksha* system, this zero point of Aries is 180° exactly opposite the

star Spica (chitra). The western astronomers, however, follow a moving point of zero reference, i.e. the Equinox position of the Sun each year is the first degree of Aries. The zero Aries of the west is at present actually about 6¼° in Pisces of the Indian system. The angular distance between first point of the fixed Aries and of the movable Aries, is called Ayanamsa. It is (Lahiri Ephemeries or *Chitra Paksha*) 23°45'51" on 1.1.1993.

The Western astronomy follows Eqatorial Longitudes of all the heavenly bodies, while Indian classical astronomy follows sidereal longitudes. The former are called *Sayana* longitudes and the latter, *Nirayana* longitude = Sayana Longitude - Ayanamsa. The Ayanamsa changes every year by about 50.3" of an arc due to the precession of Equinoxes or due to wobbling circular motion of the Earth's axis (which is 23½° inclined to the perpendicular to the plane of the ecliptic but is also performing a conical rotation).

4. The system of measurement of time is different. Day is related to the Earth's spin on its axis and in Indian system it is measured from sunrise to next sunrise. Month is related to Moon's motion round the Earth and related to Phases of the Moon. It is measured from *amavas* to next *amavas* (Moon's exact conjuction i.e. same sidereal longitude as that of the Sun). Year is measured with Sun's sidereal (relative or apparent motion in the Ecliptic) from zero Aries to next zero Aries or from Equinox to Equinox. Thus, we have civil days, lunar months and solar

Year or about 365¼ days, with months divided into 30/31/28/29 days and each day divided into 24 hours (midnight to midnight). Further, local time was followed in Indian system while standard zonal times are followed for countries or zones in a country in the modern (Western) system. This local noon is mid-day locally and local midnight is *Ardharatri* (half point of *ratri-man*).

5. Indian system followed observations by the naked eye and calculations were by structures like **Sun-Dial**, making use of geometric shapes and algebraic and trigonometric calculations. The concepts of *Devatas* of *Mandochha* and *Sighrochha* (the point of the slowest motion i.e. Apsis, and the point of the fastest motion etc.) that is, accelerating and retarding the relative motions by pulls on the planets (of different astronomical points) in different directions (forward and retro) were followed. Later on, an epicyclic theory was adopted.

   The Western astronomy followed Kepler's laws of planetary motion, modern mathematics and detailed calculations. Telescopic observations were taken. Photographic records of position of heavenly bodies and skies were made. Spectroscopes were used to analyse light spectra, and from the study of shift of the frequencies of lights emitted by stars, their motion was determined; from the study of their individual spectra, their composition was ascertained. From parallax studies, the distance of various heavenly bodies (of planets, stars, galaxies and supernova) were estimated. With telescope of very high

resolution power, the double (twins) stars were discovered.

6. In Indian, astronomy and astrology developed as a twin science. If former is the body of this science, the latter is its soul. Both were part and parcel of this divine knowledge and were linked to philosophy - cyclic origin of the Universe, its maintenance and destruction by the Almighty Brahma and its regeneration. Jyotish was a *Vedanga*.

   In the West, astronomy developed more as a secular, physical, science.

   Both, however, tried to fix the position of planets, Sun and Stars, and determine their motion (velocities and directions). But, whereas, Indian system concentrated on angular position and motion only, the western system also worked out linear distances and linear velocities.

7. In Indian system, position and motions of certain astronomical points were studied in addition to those of physical bodies e.g. Nodal points of the Moon and various planets, Motion of the Apsis of the orbit, motion of Conjunction points, and other astrologically important positions (Mandi, upagrahas, yogas, Karanas, ascensional differences, right ascensions, meridian cusp etc.) were also astronomically calculated.

CHAPTER 2

Important Definitions

1 SPHERE

If a circle is rotated around one of its diameters, the figure so formed is a sphere. Examples of spherical surfaces are: ball, football, orange etc.

The centre of a circle is equidistant from all the points on its circumference and the centre of the circle is the centre of the sphere and equidistant from all the points on its surface.

Radius: Half the diameter of a circle or sphere is called radius. In other words, the distance between the centre of a circle or a sphere and any point on its circumference or surface is radius of the circle or the sphere.

2 CELESTIAL SPHERE

The Earth is also spherical and if the surface of the Earth is projected infinitely in the heavens, the figure so formed will be celestial sphere.

In other words, celestial sphere is a sphere of infinite radius compared with any distance on the Earth, so that the Earth occupies the position in the

centre of this imaginary sphere.

It can be explained as under:

If two persons are standing at two diametrically opposite points on the Earth, each will see an apparently concave hemispherical surface of the heavens. If both the hemispherical surfaces are joined, a celestial figure of a sphere is obtained.

3 GREAT CIRCLE

Any plane passing through the centre of a sphere cuts the surface in a circle which is called a great circle, or

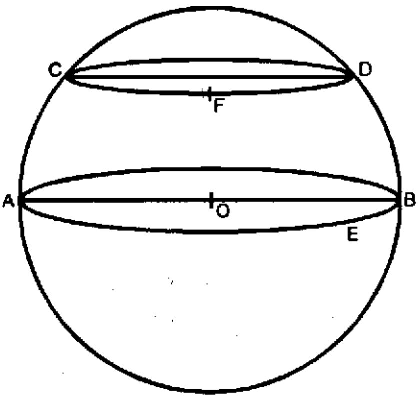


Figure 1

A great circle on the surface of a sphere is a circle whose diameters pass through the centre of the sphere i.e. the centre of the sphere is the centre of the great circle AOB is a diameter of the sphere. The circle AEB is a great circle in figure 1. A great circle always divides the sphere in two hemispheres.

4 SMALL CIRCLE

Any plane not passing through the centre of the sphere cuts the surface of the sphere in a small circle. Its diameter or radius is shorter than the diameter or radius of the sphere or great circle. Circle CFD is a small circle in figure 1.

5 PLANE

If a plane surface is extended infinitely, it is called

a plane (in mathematical terms) i.e. if the top of the smooth table is extended infinitely, the surface so formed by the top of the table will be a plane.

6 POLE OF A CIRCLE IN A SPHERE

The concept can be well explained with the help of the figure 2.

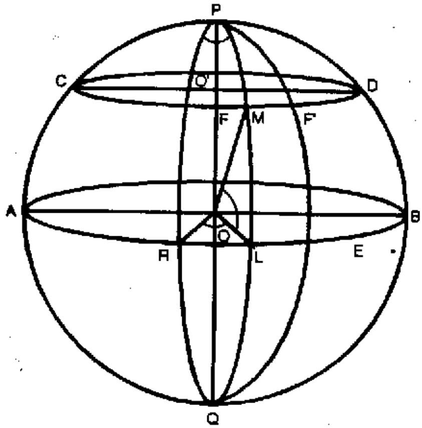


Figure 2

In figure 2, APBQ is a sphere whose centre is O. The plane AEB cuts it and makes a great circle AEB whose centre is O.

The plane CFD which is parallel to the plane AEB is cutting the sphere in a small circle with its centre at O'. Now OO' is produced upwards and downwards to meet the sphere at P and Q. The points P and Q are the poles of circles on the parallel planes to these circles.

The properties of the pole are:

(1) The straight line joining the poles cuts the circles at right angles of which these are poles.

(2) The lines on the surface of the sphere joining the two poles also form an angle of 90° with these circles.

(3) A pole has only one great circle on which the line joining the poles form a right angle.

(4) Every great circle will have two opposite poles on the sphere, where all lines (circular) drawn

at right angles to the circumference of the said circle will meet.

7 TERRESTRIAL EQUATOR

In the figure 2 on the prepage, let the Earth be the sphere, P and Q be its poles, the great circle AEB will be the terrestrial Equator. The terrestrial Equator is a great circle drawn round the Earth but perpendicular to its axis. The Earth's axis is passing through its North Pole P and South Pole Q. In the figure 2 P and Q are called the terrestrial poles.

Terrestrial Meridians: Any great circle terminated by P and Q is a terrestrial meridian. In the figure 2 the curved lines joining the poles of the Earth P and Q are terrestrial meridians.

First Meridians: Principal Meridian: The meridian passing through Greenwich observatory (near London in England) has been regarded as the principal meridian by universal agreement.

8 TERRESTRIAL LONGITUDE

Let PRQ (figure 2) be the principal meridian, cutting the Equator at R, and let PLQ be any other meridian cutting the Equator at L. The angle subtended by these two meridians is called longitude i.e. angle $\angle$ROL is the longitude of meridian PLQ there O is the centre of the earth. If this meridian is in east of the prinipal meridian, the longitude will be east and if it is in west, the longitude will be west. Spherical angle RPL between the two meridians (one is the principal meridian) at the pole also measures the terrestrial longitude of the meridian PLQ.

9 TERRESTRIAL LATITUDE

In figure 2, let M be a place at meridian PMLQ,the meridian cutting the Equator at L. The great circle arc ML is the latitude of the place. Angle ∠MOL will also represent the same thing (as the great circle arc will also be measured in angles). If the place is in North of Equator, it is called north and if it is in south, it is called south. All the places lying at one meridian will have the same longitude.

All the places lying at the small circle passing through, say, M, and parallel to the Equator will have the same latitudes. So, latitudes are also defined as parallel circles to the Equator at different angular distances i.e. all the places lying on the circle CMFD will have the same terrestrial latitude.

Note : Celestial Poles, Celestial Equator, Celestial Longitude, etc. will be written Pole, Equator, Longitude in the following pages.

10 CELESTIAL POLES

If the axis of the Earth is extended infinitely it will cut the celestial sphere at two points known as celestial poles. The extension of the axis northwards will meet at the North Pole and extension of the axis southwards will meet at the South Pole.

11 CELESTIAL EQUATOR

Celestial equator is the great circle on the celestial sphere whose plane is at right angles to the direction of Celestial pole.

It can also be termed as the projection of Earth's Equator on to the celestial sphere. The great circle thus projected on the celestial sphere will be known

as the celestial Equator.

12 ECLIPTIC

Ecliptic is the apparent annual path of the Sun amongst the fixed stars on the cosmic sphere. It is inclined at 23°28' to the celestial Equator.

Actually it is the Earth that is moving round the Sun. So exactly it is the projection of the earth's annual path round the sun on the cosmic sphere.

13 ZODIAC

Zodiac is an imaginary belt of about 9° north and 9° south of the ecliptic where the Moon and all the planets have their movement.

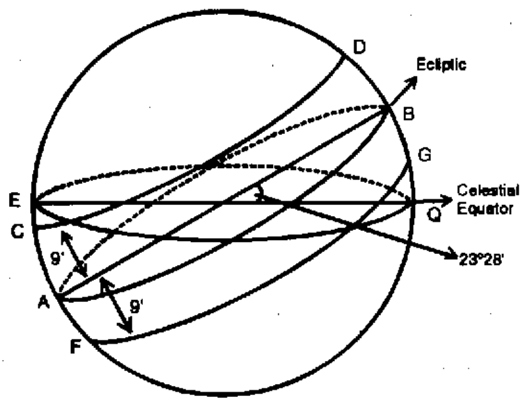


Figure 3

In the figure 3 of the celestial sphere, EQ is the celestial Equator, AB is the ecliptic inclined at angle of 23°28' to the Equator, CD and FG are circles parallel to AB at a distance of 9° in north and south. The belt between CD and FG is known as Zodiac and ecliptic is in the middle of this belt i.e. the space covered by CAF moving around the sphere passing through D and G is known as Zodiac.

The following are the definitions which are explained in 2.17.

Celestial Latitude of a heavenly body is its

distance from the ecliptic measured north/south of the ecliptic on an arc perpendicular to it.

14 CELESTIAL LONGITUDE

Celestial Longitude of a heavenly body is the angular distance between the first point of Aries and an arc perpendicular to the ecliptic drawn through the body. It is also defined as angular distance of the heavenly body measured along the ecliptic from the reference zero point.

15 THE DECLINATION

The declination of a heavenly body is its angular distance from the Equator measured on an arc perpendicular to the celestial Equator drawn through the body.

16 THE RIGHT ASCENSION

The right ascension is the angular distance between the first point of Aries and an arc perpendicular to the celestial equator drawn through the body, this first point of Aries being on Syana system i.e. the Vernal Equinox.

17 In figure 4, S is the star,

EOE' is the Equator,

AOB is ecliptic,

OO' points. of inter-section of EE' and AB,

O is the first point of Syana Aries (Vernal Equinox),

P & Q are North and South poles,

P', Q' are Ecliptic poles,

P'SN is perpendicular from P' on ecliptic through S,

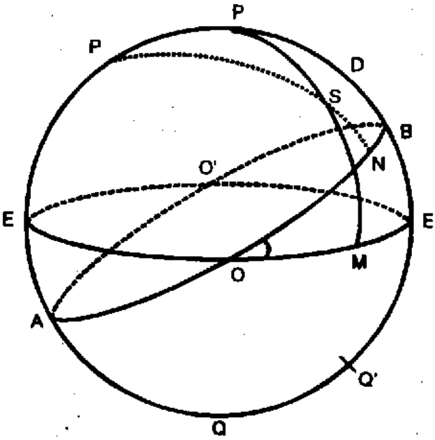
PSM is perpendicular from S to Equator,

Arc SM is Declination

Arc OM is Right Ascension (RA),

Arc SN is Latitude,

Arc ON is Longitude (Syana).



Celestial Sphere

Figure 4

Note: The definitions of **terrestrial** latitude and longitude are totally different from those of **celestial** latitude and longitude.

18 DECLINATION CIRCLE

Parallel of Declination is a small circle through the star parallel to the celestial Equator. Each star rotates round the celestial pole on its parallel of declination.

Secondaries to a great circle are the great circles which are perpendicular to it. Thus, meridian through a star will be a secondary through it on the celestial Equator.

19 HOUR ANGLE

The angle which the meridian makes through a star with the observer's meridian is known as hour angle. When the star is at the observer's meridian its hour angle is zero. It is said to transit or culminate. Then star's meridian moves gradually towards west and completes a circle (with the Earth's rotation being West to East) in 24 hours. When the star is to

the West of the observer's meridian, its hour angle is between 0 hour and 12 hour; when it is in the East its hour angle is between 12 hour and 24 hour.

20 ALTITUDE

The altitude of a heavenly body is its distance from the horizon measured on the vertical drawn through the body, form the zenith of the observer to the horizontal circle. It has been explained in figure 5 below.

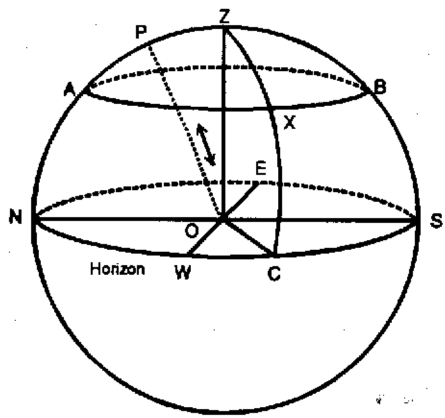
21 AZIMUTH

Azimuth of a heavenly body is its angular distance on the horizon between the North point of the horizon to the foot of the vertical drawn through the body from the zenith of observer as explained below.

NCS is the horizontal great circle called horizon, O is the observer and Z, the Zenith.

P is the North Pole, and X a star.

The plane NCS, the horizon, is at right angles to OZ.



Celestial Sphere
Figure 5

Great circle ZXC is perpendicular to the horizon meeting at C.

CX is altitude of the star. AXB (small circle) is called the parallel of altitude. Vertical circle through P and Z cuts the horizon at S and N. The point S is

the south point and N, the north point of the horizon. The west (W) and East (E), also cardinal points on horizon, have an angle of 90° from N and S points.

The arc NC expressed in the angle is called the Azimuth (W) as it is towards west.

Thus, the position of a heavenly body can also be described completely with reference to the horizon.

22 ZENITH

Zenith is the point of intersection of the celestial sphere with the plumb line produced upwards i.e. a point on the celestial sphere which is vertically above the observer's head.

23 NADIR

Nadir is the point of intersection of the celestial sphere with the plumb line produced downwards i.e. a point on the celestial sphere which is just below the observer's foot.

24 CELESTIAL MERIDIAN

Celestial meridian is a great circle passing through the celestial poles and zenith of a place. It is also called observer's meridian or prime meridian.

25 VERTICALS

Great circles drawn perpendicular to horizon form the zenith are called verticals. These are also called secondaries to the horizon.

26 PRIME VERTICAL

The vertical drawn due east and west and at right angles to the celestial meridian is the prime vertical

of a place.

Changes in the Sun's Declination

At the spring (Vernal) equinox the declination of the Sun is zero, it being at A (Figure 6) on 21st March, this point is also the first point of movable (Syana) Aries. The declination increases every day as the Sun is moving on the ecliptic until it reaches the point C (Figure 6), the point of greatest declination i.e. 23°28'(N). This point is called the **summer solstice.** It happens on or about 21st June. After that the declination of the Sun starts decreasing as the Sun starts moving southwards. It decreases and becomes zero on (or about) 23rd September when the Sun reaches at B (another point of intersection of ecliptic and Equator). Now the Sun goes to south of the Equator and its declination becomes south. It reaches at point D on (or about) 21st December which is called the **Winter Solstice.**

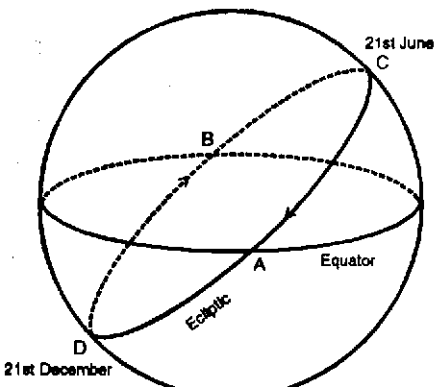


Figure 6

The declination of the Sun becomes 23°28'(S) after that the Sun starts moving Northwards and its

south declination decreases gradually till it reaches zero on 21st March.

Sun's declination at Vernal Equinox on 21st March is 0°.

Longitude and RA = 0°

Sun's declination at Summer Solstice on 21st June is 23°28'(N).

Longitude and RA = 90°

Sun's declination at Autumnal Equinox on 21st September is 0°.

Longitude and RA = 180°

Sun's declination at winter solstice on 21st December is 23°28'(S).

Longitude and RA = 270°

It is also pointed out that the latitude of the Sun is always zero as it moves along the ecliptic.

When the Sun starts moving northward from position D (Figure 6), it is said that the Sun has become *Uttrayan* and it remains uttrayan from D to C i.e. 21st December to 21st June and becomes *Dakshinayan* while moving from C to D i.e. during the period 21st June to 21st December.

Obliquity of Equator and Equinoxes

The angle between the planes of Ecliptic and Equator is 23°28'. It is said to be the obliquity of the ecliptic to the Equator.

Every year on two days the Sun crosses the Equator and its diurnal path almost coincides with the Equator rising in the east and setting in the west. One-half of its diurnal path is above the horizon and the other half below. So the day and night are equal

on these two days. These two points are called equinoxes. When the Sun is going from south to north of the Equator, the point of intersection with the ecliptic is called the first point of (Sayan) Aries and when it is going from north to south, it is entering Libra. The position of first point of Aries occurs on or about 21st March and that point is called spring Equinox or Vernal Equinox. When the Sun is on the other point i.e. about 23rd September, that point is called the Autumnal equinox.

The altitude of the star is greatest when it is on the meridian i.e. when the star is on the observer's meridian, it is at upper Culmination or in transit. After that the altitude starts declining.

The altitude of the celestial pole at any place is equal to the latitude of the place i.e. at Equator it will be zero which means the poles will lie on the horizon.

CHAPTER 3

General

Before proceeding to the Solar System, we may explain the terms stars, planets and satellites.

Stars: Stars are self-luminous bodies which emit light and heat in the space. The Sun is a star. Stars are grouped into constellations.

Planets: Besides the fixed stars, the Sun and the Moon, there are other heavenly bodies visible to the naked eye and moving around the Sun. As their motion is whimsical among the fixed stars, they are called **planets** or wandering stars. A fixed star appears twinkling while the planets shine with steady light. The planets which can be seen by the naked eye are Mercury, Venus, Mars, Jupiter and Saturn, while the other planets Uranus, Neptune and Pluto are seen only with the help of telescopes.

Satellite: Satellites are those heavenly bodies which move around the planets and in turn move around the Sun along with the planets and are normally called moons of the planets, like the Moon which is a satellite of the Earth.

Solar System: The Solar System made up of the

Sun, planets, satellites, comets, minor planets, and interplanetary dust, gas etc. It is a very small part of the Universe and seems important to us only because we happen to live inside it.

As the Sun is also a star and is at one focus of the orbits of all the planets revolving around it, the system is called the Solar System. In this system, only the Sun is emitting light. Rest of the family members of the Solar System are revolving around it and are non-luminous. The other important members of this family viz. the planets, satellites to various planets, comets, minor planets, meteors, meteorites etc. also form part of the Solar System.

Our Solar System is centred round the Sun and the planets are moving in elliptical orbits around it. There are nine planets in all i.e. Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus, Neptune and Pluto, out of which we are living on the planet Earth. Our ancients could see Mercury, Venus, Mars, Jupiter 'and Saturn (in addition to the Sun and Moon which are also called planets (*grahas*) in astrology) by the naked eye. Actually, both of these are not planets. While the Sun is a star, the Moon is a satellite. But the word *Grahas* is loosely understood as planets.

With the invention of telescope, several other large planets and many small ones could also be seen. The names of the planets known at present in their order of distance from the Sun are:

inner planets or inferior planets	Mercury Venus Earth

outer planets or superior planets	Mars The asteroids Jupiter Saturn Uranus (Herschel) Neptune Pluto

Their orbits are shown in order of their distance from Sun i.e. the nearest orbit to the Sun is nearer and the farthest orbit is away from the Sun. (figure 7).

The planets whose orbits are between the Sun and orbit of the Earth are called inner or interior or inferior planets i.e. Mercury and Venus are inner planets. While the planets whose orbits lie outside the orbit of the Earth are called outer or exterior or superior planets. Mars, the asteroids, Jupiter, Saturn, Uranus, Neptune and Pluto are the exterior, outer planets or superior planets.

Sun: The Sun is the most important of all the heavenly bodied to the inhabitants of the Earth. Its rays supply light and heat etc. not only to the Earth and those who live on it us but to the other planets and other family members of the Solar System. The Sun controls the motions of all its family members. Its influence on our day-to-day life is supreme and we cannot imagine our existence without it.

Its diameter is 865,000 miles, its volume is 1,300,000 times that of the Earth, and its mass is 330,000 times the mass of the Earth. It is producing energy by a nuclear reaction, converting hydrogen into helium and losing its mass at the rate of 4 million tons per second. It lies well away from the centre of the Galaxy, near the edge of a spiral arm. The distance

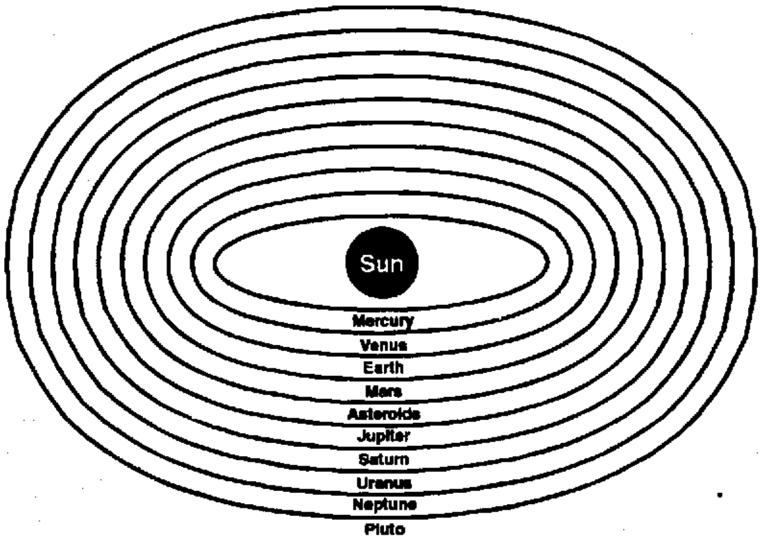


Figure 7

between the Sun and the galactic centre is about 30,000 light years. It is sharing the general rotation of the Galaxy with velocity about 135 miles per second and takes 225 million years to complete one revolution.

Ecliptic: Ecliptic is a great circle on the celestial sphere whose plane passes through the Earth which is at its centre. It is the apparent yearly path of the Sun round the Earth in that plane. Here we have assumed that the Sun is moving round the Earth. If Sun was to move in a circle round the Earth, the diameter of its disc would not have changed at different times during a year it goes through a regular cycle of changes throughout the year. Being 32'36",It is greatest in early January and it is least in early July, when it has a value 31'32" which shows that in early January it is nearest to Earth and in early July it is farthest from it. The difference between the two values of the disc is not much and, therefore the path

is nearly, circular.

Earth: The Earth is the planet on which we live. Though we claim that we know a lot about our planet but the fact is that our knowledge about the planet is very limited.

It is the third planet in order of the distance from the Sun. The mean distance from the Sun and the Earth is 92,957,209 miles. As the orbit of the Earth is not a perfect circle, it is an ellipse, and the Sun is at one of its foci. The minimum distance (when the Earth is at perihelion) is 91,400,000 miles and the maximum distance (at aphelion) is 94,600,000 miles. Its mass is about 6×10^{21} tons and its mean density is 5.52 times that of water. Its atmosphere is made up of nitrogen (77.6 per cent) and oxygen (20.7 per cent). Earth is not a perfect sphere but is called an oblate spheroid. Its diameter is 7,926 miles when measured along with the Equator and 7,900 miles as measured through the poles.

The lengths of one degree latitude at different parts of the Earth are as under:

at the Equator	=	68.704 miles per one degree	
at latitude 20°	=	68.786	do
at latitude 40°	=	68.993	do
at latitude 60°	=	69.230	do
at latitude 80°	=	69.386	do
the arc of Equator for one degree	=	69.17 miles	
	=	60 nautical miles	

The Earth is revolving round the Sun in an orbit nearly circular and it completes one revolution

around the Sun in nearly 365¼ days.

The Earth is rotating round its axis from west to east and it causes the formation of day and night and the daily revolution of the Sun and fixed stars from east to west. The axis of the Earth is perpendicular to its Equator i.e. its North Pole is on one end of the axis and its South Pole on the other. In turn, the North Pole of the Earth is facing the Polar Star.

Change of Appearance of Sky Due to Change of Place of Observer on the Earth

When the observer is at the Equator, his horizon will be great circle passing through the poles (see figure 8) and poles will be on the horizon. If a person on the Equator likes to see the Pole star, he can see just on the horizon in the North direction i.e. at the point where the Earth and sky appear to be meeting.

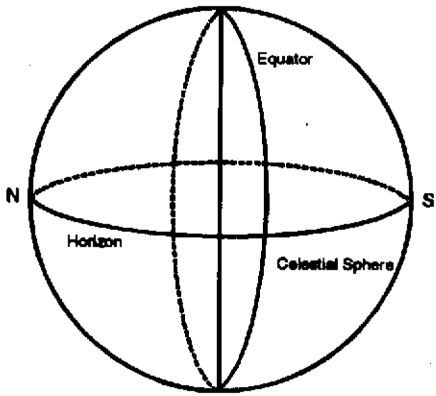


Figure 8

As the observer starts moving northwards, the Polar Star will appear to rise in latitude which can be seen in figure 9. Let the observer be at O. His horizon will be a great circle AB and he will be seeing that the Polar Star has an angle equal to the latitude of the place of observer.

The Polar Star will go on rising and will be seen above observer's head i.e. in the zenith, when he

reaches at the North Pole of the Earth (see figure 9). In this case, his horizon coincides with the celestial Equator.

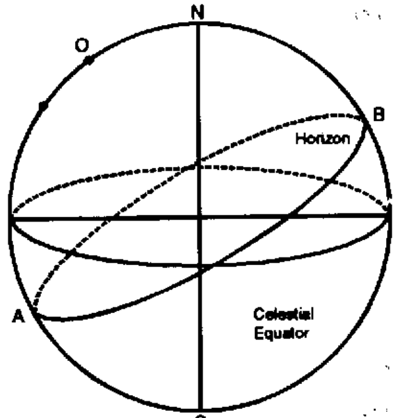


Figure 9

As the observer goes to the South of the Equator, the Polar Star will be below the horizon of the observer and he will not be in a position to see it.

From the above diagrams it will be noticed that an observer can see only half the sky at a time while on the Earth and half the sky below the horizon is invisible to him.

FORMATION OF SEASONS

Seasons are formed due to the constant obliquity of the Earth's axis with the plane of its orbit (90° - 23°28' = 66°32').

The Earth is revolving round the Sun and completes one revolution in a year = 365.2422 days which is also called the tropical year.

In the figure 9A the Earth is revolving round the Sun. EQ is the Equator, AB and MN are tropics of Cancer and Capricorn respectively. ab and mn are the arctic and antarctic circles. N and S are North Pole and South Pole respectively of the Earth, and NS is the axis which is inclined at an angle of 66°32' to the ecliptic. O is the centre of the Earth. Consider the paper on which the figure is printed as the plane of ecliptic, the axis NS is inclined to the plane of paper

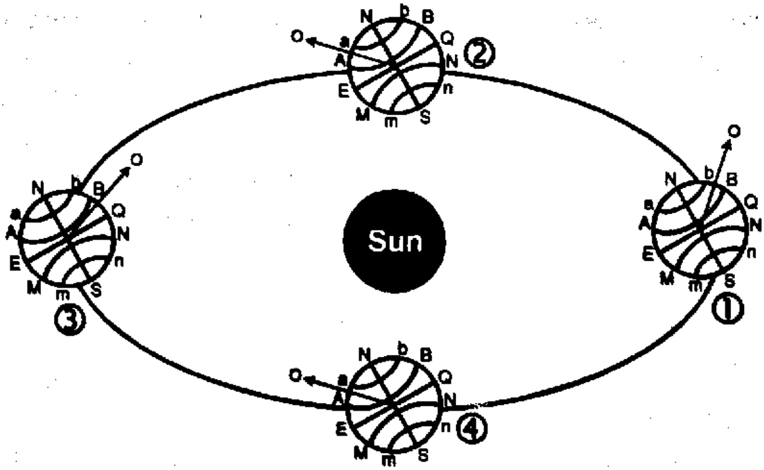


Figure 9A

by 66°32' in all the four positions. *In position 1, the Earth is at summer solstice (right-side figure).* In this case, the North Pole is bent towards the Sun.

The Sun is making an angle of 90° with the tropic of Cancer i.e. it is shining vertically at it and there is no light at the South Pole as seen by the position 1 in figure 9A. Where the South Pole remains in continuous darkness i.e. continuous day on the North Pole and 6 months night on the South Pole. This happens on 21st June every year. In this case, the Sun remains above horizon for more than twelve hours in Northern hemisphere and less than 12 hours in the Southern hemisphere "and it is summer in Northern hemisphere but winter in Southern hemisphere".

Earth at the winter solstice (left-side figure) in position 3.

The Sun is making an angle of 90° with the tropic of Capricorn and the North Pole is away from the Sun making an obtuse angle. In the case the position is

reverse of position 1 i.e. in the Northern hemisphere nights are longer (of more than 12 hours duration), winter season. It is middle of 6 months long night at the North Pole and middle of 6 months long day on the South Pole. In the Southern hemisphere, the days are longer than nights and season is summer. This happens on about 22nd December every year.

Earth on Vernal Equinox and Autumnal Equinox

In positions 4 and 2, the Earth is on the vernal and autumnal equinoxes. On these times the Sun shines vertically on the Equator of the Earth and both the hemispheres and both the poles are equidistant (angular) from the Sun. It happens on about 21st March and 23rd September every year. The days and nights are of equal duration all over the world.

In position 1, the Earth is at a greater distance form the Sun (near aphelion point) and Northern Pole is inclined towards the Sun while the Southern Pole is away from the Sun. In position 3, the situation is reversed. The seasons are not due to the distance of the Earth from the Sun but there are two reasons for it: (1) The Sun remains for a longer time above the horizon every day in summer than in winter. (2) In summer, the Sun attains a greater meridian altitude than in winter i.e. the rays fall more slanting in winter than in summer. It can be illustrated as under:

From S (Sun), rays AB are falling on the Earth and covering lesser area AB in cone SAB. With the similar cone SCD the rays are covering more area CD on the Earth which can be explained in the way that shorter surface AB is receiving the same amount of heat as CD (which is greater surface) is receiving.

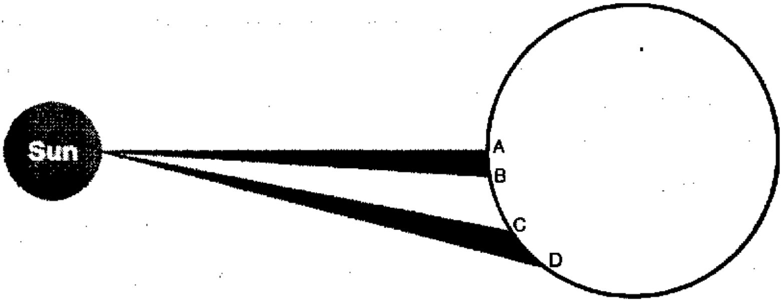


Figure 10

The amount of heat received by the unit area in AB will be more than that of CD. So, AB will be hotter than CD.

THE MOON

Moon is the Earth's only satellite. Moon is the most important of all the heavenly bodies to us after the Sun. It is also having its diurnal motion from east to west like other heavenly bodies due to rotation of the Earth on its axis. Like the Sun and other planets, it is also moving among the fixed stars in opposite direction (west to east) making a complete revolution in about 27 days 7 hours and 43 minutes i.e. 27.3217 days i.e. the sidereal month is defined to be the interval given by the Moon's complete circuit of the stars as seen from the Earth, being its mean value, 27.3217 mean solar days.

The synodic month of the Moon is the period from one *amavasya* to another *amavasaya* and is 29.5305887 mean solar days. It is more than sidereal month, because during the Moon's one revolution, Sun too moves by about one sign, and some more time is required for the Moon to catch up with the Sun to have next conjunction (*amavasaya*).

If the Earth's force of gravitational attraction is to be considered, the orbit of the Moon would have been an ellipse but due to the Sun's attraction and that of other planets, the orbit undergoes into considerable hanges. Its mean distance from the Earth is 238,000 les wh h varies from 221,460 miles at perigee to 252, 700 miles at apogee.

Owing to these perturbations, the direction of its perigee is altering. The time taken by the Moon in moving around the Earth from perigee to perigee is known as animalistic month which is equal to 27.5546 mean solar days.

A nodical month is the time taken between two successive passages of the Moon through ascending node which is equal to 27.2122 mean solar days.

The Moon's orbit can be inclined to the ecliptic maximum by an angle of 5°15' on either side of the ecliptic i.e. North and South latitudes of the Moon will never exceed 5°15'.

Moon's apparent diameter varies between 29'22" and 33'31" and the mean diameter is 31½' nearly. The albedo is low which is about 7 per cent only (i.e. only 7 per cent of the light received by it is reflected). The surface gravity is only one-sixth that of the Earth.

The Moon is having a captured rotation i.e. it keeps the same face turned towards the Earth. We can see 59 per cent of the total surface of the Moon at one time or another.

Man first reached the Moon in July 1965 when Neil Armstrong stepped out from spacecraft Eagle.

CYCLE OF MOON

Meton discovered in 433 BC that in every 19 years there are 235 lunations i.e. $365.25 \times 19 = 6939.75$ days in 19 years and $29.5305887 \times 235 = 6939.688$ days in 235 lunar months. It shows that all the phases of Moon will occur again on the same days of the month as 19 years ago, the only difference being that they will occur about one hour earlier. It is called *metonic cycle.* It gives a readymade method of predicting dates of *purnima, amavasya* etc. without much calculations. Study of ancient Hindu astronomy shows that Metonic cycle was known to our rishis and they added 7 *adhik* or extra lunar months in 19 solar years to produce an exact correspondence in solar years and lunar years (year of 12 lunar months).

CHAPTER 4

General

We have already studied in chapter 3 that the planets are moving around the Sun in elliptical path and that the Sun is at one of their foci.

Though there is no direction in the space, all directions are relative ones. Suppose you are standing in front of a pedestal fan which is moving in the clockwise direction. If you stand behind it, you will see it moving in anticlockwise direction, which is our direction too round the Sun.

For the inner planets, a planet will be called in *inferior conjunction* when it come between the Earth and the Sun and in *superior conjunction* when the Sun is between the Earth and the planet. Conjunction is actually due to the two being in the same line of our sight.

For superior or outer planets, a planet will be said to be in opposition when the Earth is in between the Sun and the planet. An outer planet can never come in between the Sun and the Earth and cannot have an inferior conjunction. It has superior conjunction when it is on the far side of the Sun.

MERCURY

Mercury is the first planet in order of distance from the Sun i.e. it is the nearest planet to the Sun. It was earlier believed that Mercury had captured rotation (88 Earth days), but now it is known that the real rotation period of Mercury is 58.65 days, approximately two-thirds of a Mercurian year. The interval between one sunrise to another will be 176 days or two Mercurian years. The orbit of Mercury is more eccentric than of other planets of the Sun except Pluto. The maximum distance of Mercury from the Sun is 43,000,000 miles and the minimum disteance is 28,000,000 miles which is due to the orbit being more eccentric. Maximum inclination of its orbit is about 7° on either side of the ecliptic. Its diameter is about 3000 miles.

VENUS

Venus is second nearest planet to the Sun i.e. after Mercury it is the next planet nearest to the Sun.

The maximum inclination of its orbit to the ecliptic is about 3°24' on either side of the ecliptic. It is brighter than any other planet or star and casts its shadow many times. Its mean distance from the Sun is about 67 million miles and its diameter is about 7,500 miles.

Venus and Mercury are inner planets which can be seen near the Sun (either east or west). These are therefore called the morning or evening stars as they are visible either just after the sunset or before the sunrise.

Its sidereal period of revolution is 224.7 days, but synodic period (with the Sun) is 584 days.

MARS

Mars is the fourth planet in order of distance from the Sun and the nearest outer planet to the Earth. Its diameter from the Sun changes from 127,000,000 miles to 153,000,000 miles. Its diameter is 4,200 miles. When the Mars is closest to us, it is within 35 million miles form the Earth and it occurs when the Mars is at the least distance from the Sun and the Earth is at the greatest distance from the Sun. In this case the planet outshines the other stars except Venus. But when it is the faintest, it sinks to the second magnitude and can be confused with a star. Near the quadrature, it appears strongly gibbous. Its sidereal period of revolution is 687 dyas and synodic period is 780 days.

There are two satellites of Mars, named Deimos and Phobos, which were discovered on 5 September, 1877 when the Mars was in opposition.

JUPITER

Jupiter is the largest planet. It is more massive planet than all the other planets combined together. Its mass is only 1/1047 times of the Sun. As it flattens on the poles, its Equatorial diameter is over 88,000 miles and polar diameter is less than 84,000 miles. Its mean distance from the Sun is 483.3 million miles. Its sidereal period is 11.9 years.

Jupiter shows yellowish disc, crossed by famous cloud belts.

There are sixteen satellites of which the most important are four, namely, Io, Europa, Ganymede and Callisto.

When seen through a telescope, a number of bright belts or bands are seen encircling the planet parallel to its equator which may be of clouds or vapours in its atmosphere.

SATURN

Saturn is the sixth planet in order of distance from the Sun. Its mean distance from the Sun is 886 million miles and diameter is about 74,000 miles. Its density is less than water. It is much larger and more massive than any other planet (except Jupiter). Its orbit is nearly circular and inclined about 2½° to the ecliptic. It is surrounded by circular rings which do not touch the surface of the planet. Formerly, only nine satellites were known but now 20 of its satellites have been discovered. Its sidereal period of revolution is about 29.5 years. Its synodic period (with the Sun) is only 378 days.

URANUS

Uranus was discovered by William Herschel in March 1781. The planet is known as Herschel also after the name of its discoverer. Five satellites are known till now. It is very far. Its distance is about 1783 million miles and its diameter is only about 32,000 miles. Hence, it is invisible to the naked eye. It is also very dim.

NEPTUNE

As a result of calculations by Leverrier and Adams, Neptune was discovered in 1846 by J Galle and H D Arrest, at the Berlin observatory. Its distance is 2793 million miles and sidereal period 164.8 years. Its brightness is even much less than that of Uranus,

and it is very faint.

PLUTO

The pluto is the ninth planet. It was discovered by Clyde Tombaugh in 1930. Its orbit is most eccentric of all the planets. For most of the 248 years period, it is much further out than Neptune; but near, perihelion, it is closer to Sun than Neptune. Its mean distance from the Sun is 3667 million miles, and its diameter merely 1800 miles, and extremely low magnitude.

COMETS

Comets differ widely from the planets, both in their physical state and in the nature of orbits described around the Sun. Comets are generally a brilliant nucleus surrounded by nebulous matter stretching out into an elongated tail. All the comets do not develop tails and many are nothing more than tiny patches of luminous haze in the sky. They appear shining due to the reflection of sunlight by them.

The masses and density of comets are small and can easily be perturbed by planets. They appear suddenly in the sky and can be seen for some days, weeks, or months and when they reach near the Sun and then recede from it and disappear.

The comets whose motion can be calculated and the dates of their return predicted are called periodic comets. The motion of some comets is direct while that of others retrograde. It is to be noted that the motion of all the planets around the Sun is in one direction i.e. direct if viewed from the Sun.

Among the 'periodic comets', Halley's comet and

Encke's comet are more remarkable.

Halley's Comet

Halley's comet was first seen in 1531 and afterwards in 1607, 1682, 1758-59, 1835, 1910 and last on 9 February 1986. It has a period of 76 years. Its next return is expected in 2061.

Encke's Comet

Its periodic/time is 3.3 years. At perihelion, it comes closer to the Sun than does Mercury and at aphelion, i.e. at its greatest distance, it is more than 4 times the Earth's distance from the Sun.

Non-periodic comets are much more numerous than periodic. These comets are seen only once and after that they are lost in the space and never come back.

Minor planets or asteroids. The diameter of the asteroids is small, and the largest of them has a diameter of 623 miles. Their orbits are very eccentric. The number of asteroids is very great which is estimated to be 40,000. Due to their low masses, the escape velocities will be low. All of them have their individual orbits in an asteriod belt between the orbits of Mars an Jupiter. But, some of these, because their orbits, are very eccentric, come inside the orbit of the Earth or even that of inner planets.

METEORS

Meteors are small particls, usually smaller than a grain of sand, moving freely around the Sun. A Meteor cannot be seen in space as it is very small but is heated by friction when it enters the Earth's atmosphere. It is destroyed but during the process it

produces luminous effect. Due to their luminous effect meteors are also called the shooting stars.

Meteorites: These are relatively larger bodies, big rocks etc., which do not get completely burnt up in atmosphere before reaching the Earth's surface, and which produce craters etc. or get buried deep.

Kepler's Laws

The laws according to which the planets move around the Sun were discovered by John Kepler (1571–1630) which are given below.

I Each planet moves in an elliptic orbit with the Sun in one of the oci.

II Equal areas are covered in equal times by the radius of the planet i.e., by the line joining the planet and the Sun.

III The squares of periodic times of the planets are to one another as the cubes of their mean distance from the Sun.

Though the three laws of Kepler have been stated, the use of the same is otside the scope of these lessons.

The Scheme Followed for Keeping the Names of the Days of a Week

In Indian Jyotish, the duration of day and night has been divided into 24 parts which is called hora. One hora is equal to an hour. The names of the days are kept on the basis of the lord of the first hora of the day. The lords of the horas are according to the planets. Now see the following scheme. Verse 31 (shloka 31) of chapter XII of *Suryasidhanta* of

Mahabir Prasad Srivastava, Edition II.

मन्दामरेज्यभूपुत्र सूर्य शुक्रेन्दुजेन्दवः
परिभ्रमन्त्यधोऽधस्तात्सिद्धविद्याधरा धनाः ॥३९॥

According to the shloka, the orbits of revolution around the earth of the various planets are in the order of Saturn, Jupiter, Mars, Sun, Venus, Mercury and Moon. Keep the planets in a circle in this order.

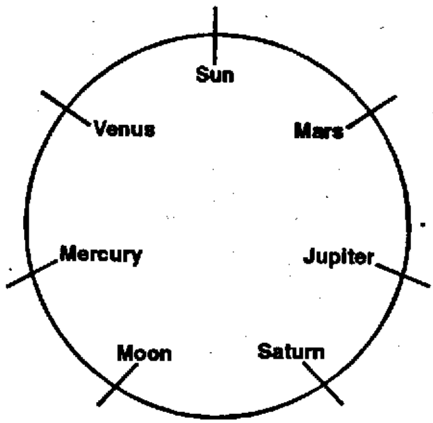


Figure 11

This order is actually the order of the planets in their decreasing sidereal period or increasing angular motion, Saturn being the slowest and the Moon being the fastest.

Now we start from Sunday (the name kept after the lord of first hora), the second hora on Sunday will be of Venus (counting anticlockwise), the third hora of Mercury, the fourth of Moon, the fifth of Saturn, the sixth of Jupiter, the seventh of Mars, the eighth of the Sun and so on the fifteenth of the Sun the twenty second of the Sun, twenty third of Venus, twenty fourth of Mercury, twenty fifth hora i.e. first hora of the next day will be of the Moon, so the next day was named after Moon i.e. Monday.

Now we count from Moon.

Hora	1	2	3	4	5	6
Lord	Mon	Sat	Jup	Mars	Sun	Ven
Hora	8	15	22	23	24	25
Lord	Mer	Mon	Mon	Sat	Jup	Mars

twenty fifth hora is the first hora of the next day, so the day was named after Mars (*मंगल*) the name of day (*मंगलवार*) i.e. Tuesday. Similarly, of other week-days were named as given in the table below.

Lord of first hora	**Name of the day**	**Lord of first hora**	**Name of the day**
Sun	Sunday	Ravi	Raviwar
Moon	Monday	Soma	Somawar
Mars	Tuesday	Bhauma/ Mangal	Bhaumawar/ Mangalwar
Mercury	Wednesday	Budha	Budhawar
Jupiter	Thursday	Guru	Guruwar
Venus	Friday	Shukra	Shukrawar
Saturn	Saturday	Shani	Shaniwar

WHY THE PLANETS BECOME RETROGRADE

First of all we take up the case of an inner planet. Let it be Mercury. The Sun is in the centre around which all the planets, including the Earth, are moving. Mercury is nearer to the Sun and it completes one revolution in 88 days. The Earth is away from the Sun and completes one revolution in 365¼ days. So, the angular velocity of Mercury is faster than that of the Earth. The arrows in the figure are showing the direction in which Mercury and the Earth are moving. The arrow on zodiac indicates the direction in which the longitudes among the fixed

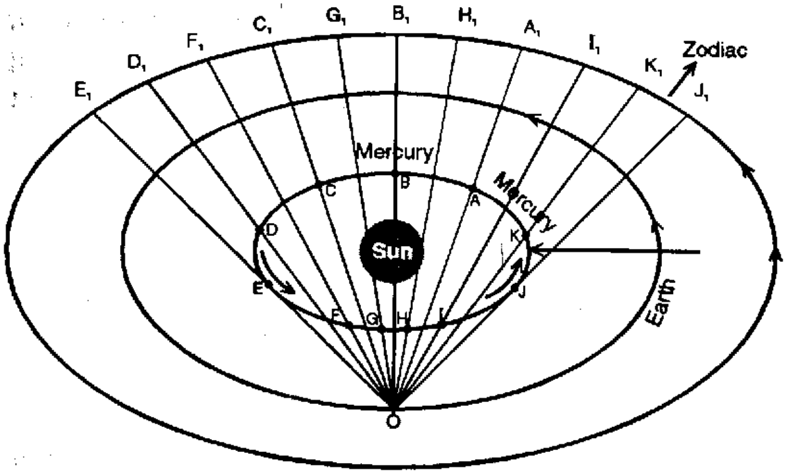


Figure 12

stars are increasing.

As the longitudes are geo-centric, suppose the observer on the Earth is stationary and Mercury is moving in the direction of arrow with a relative speed of the Earth (i.e. Mercury's speed – Earth's speed). Let the observer be at O. As we are considering the observer and the Earth to be stationary and Mercury moving with a relative speed, let the Mercury be at A and it will be seen at A_1; in the zodiac, it moves further to B and seen at B_1; in zodiac, C_1 D_1 are the corresponding positions of C and D. Here, longitudes are increasing. When it comes to E, the longitude is increasing at E_1 which is nearly the position of a tangent from the observer to the orbit of Mercury. At E, the planet will appear stationary as you will see that it is going to change its motion from direct to retrograde. It can be well understood by an example that a boy runs straight and touches a point and runs back. He will have to stop for a moment for reversing the speed. Similarly, here the planet will appear

stationalry at E. Consider its further positions F, G, H and I. It will be seen that the corresponding background at the zodiac will be seen backward at F_1, G_1, H_1 and I_1 till it reaches J and its corresponding position J_1 is seen at the zodiac. It is seen in retrograde motion as its geo-centric longitudes are decreasing. When it is at J and the line OJ_1, which is nearly tangent to the orbit of the planet, it will be seen as stationary in the zodiac as the longitudes will neither increase nor decrease for some time. Afterwards it goes to K etc. when the corresponding position in the zodiac will be K_1 etc. It will be further seen that the longitudes have started increasing i.e. the planet has become direct.

Similarly for the outer planets we can justify the retrograde motion by making the observer move and planet being stationary as the outer planets move slower than the Earth.

It is to be noticed that the inner planets become retrograde when they are in between the Earth and the Sun and the outer planets become retrograde when the Earth is in between them and the Sun i.e. they are nearer to the Earth.

Note: See *Table of Planetary Movement* on page no. 142.

CHAPTER 5

Precession of Equinoxes

By continuous observation our rishis found out that the longitudes of stars are increasing. Later on, the same phenomenon was noticed by the Greek astronomer Hipparchus (190-120 BC). They considered two possible explanations for this: (1) The stars are moving but the movements of all the stars were mostly identical which was impossible. So they discarded it. (2) The first point of Aries (which is the intersection of ecliptic and celestial equator) is shifting backward. They also observed that there was no appreciable change in the latitudes of the stars. So, they came to the conclusion that the ecliptic was a fixed plane. Accordingly, it was necessary to assume that celestial equator and the first point of Aries were moving in such a way that the longitudes of the stars were increasing. It clarifies that the vernal equinox is moving backwards. The precession of equinoxes is mainly due to the attraction of the Sun and the Moon on the protuberant portions of the Earth at the Equator. The result is that the Earth has a slow wobbling motion, so that the point in the heavens (the celestial pole) describes a small circle of about 47° angular diameter round the pole of the ecliptic. This

results also in change in the identity of the polar star from one era to another.

It can be well compared with the wobbling of the axis of rotation of a spinning-top, which has been disturbed to create wobbling from its steady spin state, when its axis gets out of the vertical.

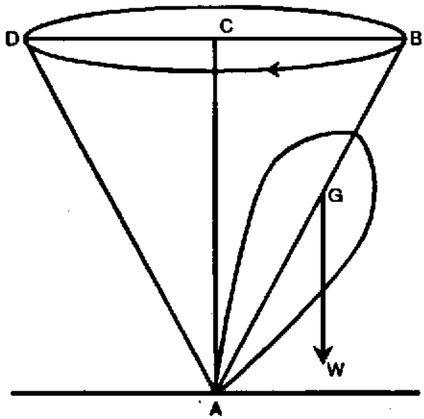


Figure 13

The weight of the top which, acting vertically downwards at G, tends to pull the axis of rotation AB away from CA (the vertical), but, due to the fast speed of spinning, it will not fall down and the axis AB will describe a cone round AC such that the angle CAB remains constant. Similarly, the expanded Earth's pole (celestial pole) is revolving round the pole of the ecliptic in a small circle. As a result of this, the Equator plane is also changing and cutting ecliptic plane at shifting point. The slow backward motion of the first point of Aries is called the precession of equinox.

When the attracting body reaches its greatest north or south declination, the disturbance is greatest and it is zero when they are on the celestial Equator. The luni-solar precession is in the ratio of 7:3 i.e. the effect of Moon's attraction is more than twice that of the Sun i.e., two-thirds of the whole. The total of the two affects amounts to about 50".35 yearly while that of planetary precession the affect is 0".11 annually.

The mean net annual precession, which is also called general precession, is about 50".24 each year, on an average.

As the distances of the attracting bodies i.e. the Sun, Moon, planets, asteroids, comets etc. change, the value of precession also changes. The circle on the celestial sphere is of only 47° diameter viz DB = 47° and takes 25,800 years to complete.

Its effect is important. Due to shifting of poles, the celestial Equator also moves and, in turn, the position of vernal equinox, that is the first point of Aries, also changes.

NUTATION

The effect of Sun's and Moon's attraction is not constant. Moon is sometimes above and sometimes below the ecliptic and therefore its pull on the equatorial bulge of the Earth is not always in the same direction as that of the Sun which results in the nodding of the celestial pole to and from the pole of the ecliptic. This nodding is called nutation. The result is that the precession is sometimes more and at other times less than its mean value by about 9 seconds of arc to either side in a period of 18 years 220 days or, say, $18^2/_3$ years in which Moon's nodes make complete revolution in the heavens.

MOVABLE AND FIXED ZODIACS

Zodiac is an imaginary belt of about 9° North or South of the ecliptic within which the Moon and all the planets (except Pluto) remain in the course of their movement.

The fixed zodiac is one in which the first point of

Aries is always fixed in the nakshatras i.e. always at an angle of 180° to Chitra star. The longitudes measured with reference to this fixed first point of Aries which has a permanent position on the ecliptic fixed among the stars are called *Nirayana* longitudes. They are divided into twelve rashis such as Mesh, Vrish etc. This fixed zodiac is also divided into 27 nakshatras. Thus the Nirayana rashis always contain the same star groups/constellations.

The other zodiac is called movable zodiac/ tropical zodiac. In this the first point of Aries is the vernal equinox i.e. the point where the ecliptic intersects the celestial Equator and it precedes by about 50".3 each year as already explained earlier in this chapter. Due to attraction of the Sun and the Moon on the protuberant portions of the Earth on the Equator, the first point of Aries moves slowly in the direction opposite to that of the yearly motion of the Sun. The longitudes measured in this system are called tropical or Sayana longitudes. The twelve signs in this system are of 30° each starting from spring equinox and these signs do not always cover the same span of 30° over the ecliptic as in Nirayana system. Under this system, the star composition of zodiac signs goes on changing with the passage of time.

The angular distance between the first point of fixed Aries and the movable Aries i.e. vernal equinox is called Ayanamsa. In other words, it is the angular distance by which the vernal equinox has moved backwards from the time the two zodiac systems coincided.

The year in which the two first points of Aries coincided is taken as 285 A.D. according to which the

Ayanamsa on 21st January 1993 was 23°45'55" (as per *Rashtriya Panchanga*). It is based on the recommendation of the Calendar Reform Committee appointed by the Government of India which adopted this system of Ayanamsa in 1953. Under this Ayanamsa system both first point Aries were deemed to have coincided on Sunday the 22nd March of AD 285 and hence Ayanamsa on that day was zero.

Therefore,
Sayana longitude = Nirayana longitude + Ayanamsa.

In Indian astrology, we use Nirayana longitudes.

DIVISION

Zodiac has been divided into twelve rashis each of 30° and their Indian names have been given according to the shape of the stars in it.

(1) Aries	= Mesha	(7) Libra	= Tula
(2) Taurus	= Vrisha	(8) Scorpio	= Vrischika
(3) Gemini	= Mithuna	(9) Sagittarius	= Dhanus
(4) Cancer	= Karkata	(10) Capricorn	= Makara
(5) Leo	= Simha	(11) Aquarius	= Kumbha
(6) Virgo	= Kanya	(12) Pisces	= Meena

From ancient times, the Nirayana zodiac has also been divided by our rashis into 27 constellations (nakshatras). These nakshatras are group of stars and each nakshatra is of $^{360}/_{27}$ = 13°20' portion of the zodiac. Their names are:

(1) Ashwini	(2) Bharani
(3) Krittika	(4) Rohini
(5) Mrigashirsha	(6) Ardra

(7)	Punarvasu	(8)	Pushya
(9)	Ashlesha	(10)	Magha
(11)	Purvaphalguni	(12)	Uttaraphalguni
(13)	Hasta	(14)	Chitra
(15)	Swati	(16)	Vishakha
(17)	Anuradha	(18)	Jyeshtha
(19)	Mula	(20)	Purvashadha
(21)	Uttarashadha	(22)	Shravana
(23)	Dhanistha	(24)	Satabhisha
(25)	Purvabhadrapada	(26)	Uttarabhadrapada
(27)	Revati		

The Nirayana rashis and nakshatras have an unchanging relationship with each other. These nakshatras and rashis are in the order as given above. Corresponding longitudes of nakshatras starting from the first point of Nirayana Aries are as shown below.

Each nakshatra has a prominent identifying star after whose name the nakshatra is called. These stars are called *Yogataras*.

After completing one cycle of 0° to 360° again the same rashis and constellation come i.e. after 360° = 0° Mesha and Ashwini start.

1. Mesha	0° to 30°	Ashwini	0°	to	13°20'
		Bharani	13°20'	to	26°40'
2. Vrisha	30° to 60°	Krittika	26°40'	to	40°
		Rohini	40°	to	53°20'
3. Mithuna	60° to 90°	Mrigashirsha	53°20'	to	66°40'
		Ardra	66°40'	to	80°
		Punarvasu	80°	to	93°20'

4. Karkata	90° to 120°	Pushya	93°20'	to	106°40'
		Ashlesha	106°40'	to	120°
5. Sinha	120° to 150°	Magha	120°	to	133°20'
		Purvaphalguni	133°20'	to	146°40'
6. Kanya	150° to 180°	Uttaraphalguni	146°40'	to	160°
		Hasta	160°	to	173°20'
7. Tula	180° to 210°	Chitra	173°20'	to	186°40'
		Swati	186°40'	to	200°
		Vishakha	200°	to	213°20'
8. Vrishchika	210° to 240°	Anuradha	213°20'	to	226°40'
		Jyeshtha	226°40	to	240°
9. Dhanus	240° to 270°	Mula	240°	to	253°20'
		Purvashadha	253°20'	to	266°40'
10. Makara	270° to 300°	Uttarashadha	266°40'	to	280°
		Shravana	280°	to	293°20'
		Dhanishtha	293°20'	to	306°40'
11. Kumbha	300° to 330°	Satabhisha	306°40'	to	320°
		Purvabhadrapada	320°	to	333°20'
12. Meena	330° to 360°	Uttarabhadrapada	333°20	to	346°40'
		Revati	346°40'	to	360°

CHAPTER 6

Phases of Moon

The Moon has no light of its own but it reflects the light received from the Sun. It revolves round the Earth and its path is inclined at an angle of 5° approximately to the ecliptic. So, the eclipse cannot take place on every *amavasya* and *purnima*. (It will be explained in the next chapter.) The Earth is in the centre with O as its centre and there are eight positions of the Moon shown around the Earth (see figure 14 on the next page). The sunrays are coming from the left. L is the centre of the Moon and O that of the Earth. Join OL and draw a perpendicular to it. Name it AB which bisects the sphere of the Moon in two hemispheres. The hemisphere towards the Earth will be visible from the Earth. The sunrays are coming from the left as the Sun is very big and at a very great distance as compared to the Moon's diameter and its distance from the Earth. We can easily assume the rays to be parallel. Draw CD perpendicular to the rays of the Sun on the Moon. The side opposite to the direction from which the sunrays are reaching the Moon will be dark as no sunrays are falling on that portion of the Moon. It has been shown as shaded. The other position on which the sunrays are falling

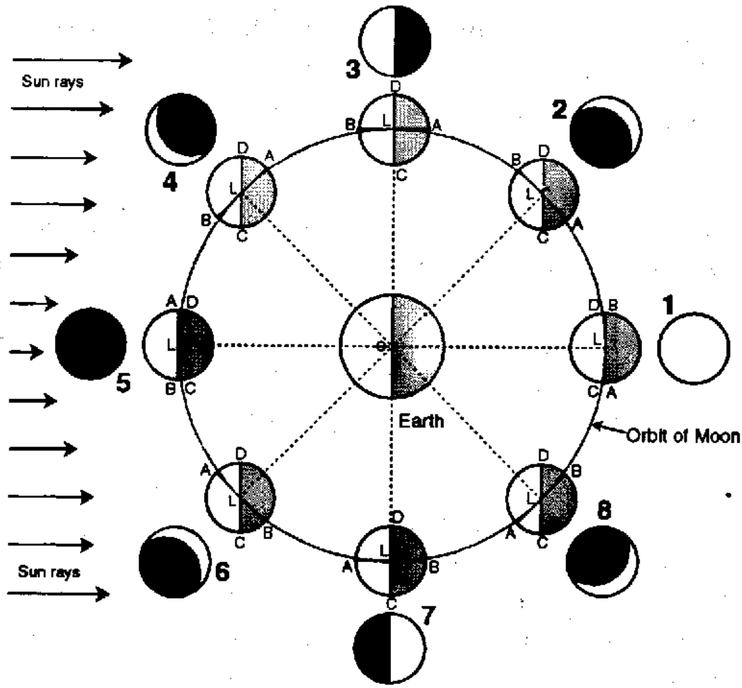


Figure 14

is left blank and this hemispherical portion is reflecting light in the space and seen by the observer on the Earth as bright portion of the Moon.

When the Moon is in the position 1 with respect to the Earth and the Sun i.e. the Earth is in between the Sun and the Moon, AB and CD coincide, the illuminated portion of the Moon being towards the Earth and the full disc of the Moon i.e. illuminated hemispherical position is seen. This is the position on *purnima*. In positions 2 and 8, about three-quarters of the disc of the Moon is seen as the portion visible are BLC and DLA which is more than half of the hemisphere of the Moon receiving light from the Sun. In positions 3 and 7, the CD is perpendicular to AB. So, only half of the illuminated hemisphere of

the Moon can be seen and as such half of the disc i.e. BLC and ALD is visible. The remaining half of the hemisphere towards the Earth is not receiving any light of the Sun; so, it does not reflect any light, and, as such, is invisible to us. It happens on '*ashtami*' days of the *shukla paksha* as well as the *krishna paksha*. The only difference is that the half disc that is bright on *shukla ashtami* is dark on *krishna ashtami* and vice versa. When the Moon is in positions 4 and 6, less than half of the disc is visible as less than half the illuminated hemisphere is BLC, ALD being towards the Earth.

In position 5, AB and CD coincide again and dark portion of the Moon is towards the Earth. So, the Moon cannot be seen and it happens on *amavasya*. The shape of the Moon seen on a particular position is also shown near each position. Here, the hemisphere of the Moon towards the Earth is shown as a circle with bright half as blank and the dark portion as black.

NODES

Nodes are the points at which the orbit of the Moon, or any planet cuts the plane of ecliptic. During the course of its movement (i.e. of the Moon or the respective planet) when the said heavenly body crosses the ecliptic plane, the crossing points are called nodes of the Moon or of the respective planet.

When the Moon or the respective planet crosses the ecliptic while going from north to south, the crossing point is called descending node. In the former case, the latitude of the Moon or the said planet is zero while changing from the positive to the

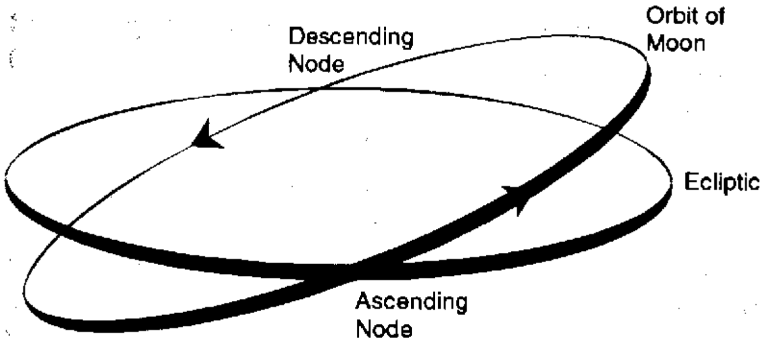


Figure 15

negative. The line joining these two nodal points is said to be the **line of nodes** or the **axis** of the nodes.

RAHU AND KETU

Rahu and Ketu are the nodes of the Moon. When the Moon crosses the ecliptic while going from south to north of the ecliptic, it is the ascending node of the Moon which is called Rahu. The latitude of the Moon at Rahu is zero and is on the increase from the negative (south) to the positive (north). While crossing the ecliptic going from the north to the south i.e. the descending node of the Moon is called Ketu. In figure 15, while there appear four points of intersection, in space (3 dimensions) there will be only two, i.e. between thick (front) lines and the thin lines only. So, Rahu and Ketu are actually not any physical planets but are the points on the plane of ecliptic where the Moon crosses it.

This is the reason for calling these two as *chhaya grahas*, i.e. shadowy planets. At these points, the Moon and the Sun get eclipsed on *poornima* or *amavasya* respectively, if on these tithis they are on or near these *chhaya grahas*. These are also called

dragon's head and dragon's tail. These points are not stationary but take about 18 years 220 days i.e. 18.60 years in making a revolution around the Earth. This motion is non-uniform like that of all planets. Given here is the average period of motion. Their motion is in reverse direction than that of other planets. In other words, they move in the zodiac in reverse direction. So, they are said to be having a retrograde motion at an average or mean rate of about 19.36° each year or about 8" an hour. They have true or mean longitudes according to whether we have used mean motion or calculated actual position.

SIDEREAL PERIOD

Sidereal period or periodic time of a planet is the time taken by it to make a complete revolution with reference to the fixed stars. In the case of the Moon it is 27 days 7 hours and 43 minutes. This is the minimum sidereal period among *nava grahas*. The maximum sidereal period is that of Saturn which is 29.46 solar years. After considering the extra Saturnine planets, the maximum sidereal period is that of Pluto i.e. 248.4 years.

SIDEREAL TIME

Time, includingsidereal time, can be measured in many ways. Sidereal day is the time elapsed since the precedding transit of Sayana first point of Aries to the next transit of the meridian of a place. In other words, one sidereal day is the time taken by the Earth in completing one rotation with respect to a fixed star which is equal to 23 hours 56 minutes and a few seconds.

This sidereal day is expressed in sidereal hours

and minutes. One sidereal day is equal to 24 sidereal hours. One such hour comprises of 60 minutes etc.

It can be observed that a fixed star which is rising along the Sun will rise about 4 minutes earlier than the sunrise next day i.e. the Sun has moved 1° in the zodiac.

If an observer continues to observe the sky for one month, he will notice that the Sun has risen 1 rashi after the fixed star. After one year, he will notice that the same star is rising again with the Sun.

As the Earth is moving round the Sun and the Sun is fixed, the earth completes one revolution around the Sun in one year. The Earth rotates around its axis once in a day. The same part of the Earth appears approximately 365 + 1 = 366 times in front of the same fixed star in a year (appro-ximately 365 solar days) or the 1st point of Aries has transited the meridian 366 times in a year of 365 days and 367 times in a year of 366 days i.e. a leap year. Therefore, a sidereal day is shorter than the solar day by 24hrs/ 365.25 = 24 × 60/365.25 = 3 minutes 56 sec approximately

SYNODIC PERIOD

Synodic period is the interval of time which elapses between two oppositions or two conjunctions of a superior planet. In case of inner-planets it is the time between two conjuntions of the same type whether they are both inferior or superior.

It can be explained as under:

The Sun is stationary. The planets (including the Earth) are revolving around it. The earth completes

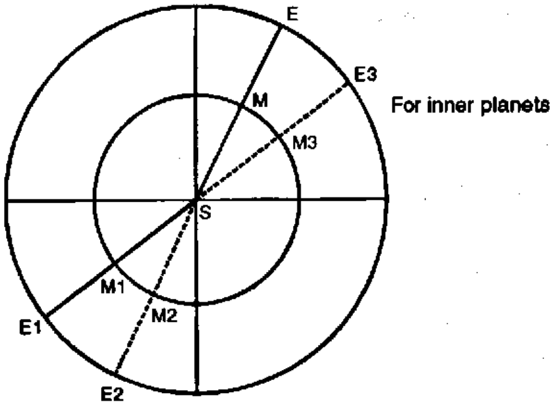


Figure 16

one revolution in approximately 365 days while Mercury completes it in 88 days.

In the figure 16, let E be the Earth, M, Mercury and S, Sun. EMS is the inferior conjunction of Mercury. Now the Earth and Mercury start moving. The Mercury completes one revolution in 88 days and when it comes at M, the Earth is not at E but it has moved ahead and the next conjunction takes place when Mercury comes at M_1 and Earth at E_1. So in moving from M and completing one revolution and after that coming to M_1 is its synodic period or the time taken by the Earth in moving from E to E_1 is Synodic period of Mercury.

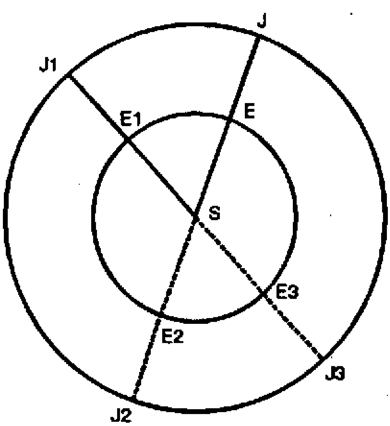


Figure 17

Similarly, for superior conjunction SM_2E_2 and SM_3E_3, the time taken by Mercury in moving from M2 and completing one revolution and coming to M_3 is its Synodic period or the time taken by the Earth in moving from E_2 to E_3 is the synodic period of Mercury.

The outer planets move slower than the Earth. Earth completes one revolution in 1 year and Jupiter does it approximately in 12 years.

Here S is the Sun, E, and E_1 are the positions of the Earth and J, and J_1 positions of Jupiter at the time of opposition, while E_2, E_3 are positions of the Earth and J_2, J_3 positions of Jupiter at the time of conjunction.

SEJ is the opposition and SE_1J_1 is the next opposition. The time taken by Jupiter in moving from J to J_1 or by the Earth moving from E and completing one revolution and then coming to E_1 is the synodic period of Jupiter.

CHAPTER 7

Eclipses

The Sun is the only illuminated heavenly body which is actually a star in the solar system and Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus, Neptune and Pluto are its planets, reflecting the light received from it. All the planets are revolving around the Sun as already explained in chapter 3. The Earth is moving around the Sun under the gravitational pull of the Sun. The Moon is moving around the Earth and along with the Earth, it goes around the Sun also, under the gravitational pull of the Earth. The Moon, in turn has its own pulling force like that of the Earth.

LUNAR ECLIPSE

A lunar eclipse takes place when the Moon passes through the shadow of the Earth in the heavens. This will only occur when all the three i.e. the Sun, the Earth and the Moon are nearly in a straight line. The Sun and the Earth are always on the ecliptic but the path of the Moon is inclined to the ecliptic at an angle of about 5°. So the Moon may or may not be on or very near the ecliptic when the Earth is in between the Sun and the Moon i.e. on poornima. When the Moon is on the ecliptic or near to it and the Earth is

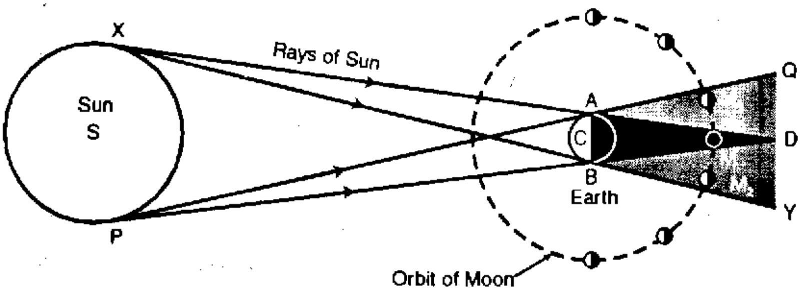


Figure 18

in between them, such a position will occur when the Moon is either on Rahu or Ketu or nearby because Rahu and Ketu are the nodes of the Moon i.e. the points where the Moon crosses the ecliptic.

When the whole of Moon's disc is obscured, the eclipse is said to be a total eclipse and when only a part of it is obscured it is said to be a partial eclipse (see figure 18).

In the figure, S is the centre of the Sun and C of the Earth. The cone ABD is not receiving any light from the Sun because the rays from all areas up to either extreme of the disc of the Sun i.e. P or X are intercepted by the Earth and the cone ABD dark-shaded is in complete darkness. Cones QAD and YBD (light-shaded) are receiving light from some part of the Sun but not from the whole disc of the Sun. The dark-shaded portion i.e. cone ABD is called **umbra** or complete shadow while the light-shaded zones i.e. QAD and YBD are called **penumbra**.

When the Moon goes from penumbra to umbra, its brightness decreases till it vanishes when it is fully in the umbra. This is the case of total lunar eclipse.

A lunar eclipse cannot occur until a portion of

Moon's surface enters in umbra. It is because in penumbra the Sun's light falling on the Moon is only diminished and not stopped directly while in umbra no direct rays from the Sun can enter.

So, when the Moon is at position M_1 or M_2 as in the figure it receives light from the one end of the Sun and hence its brightness is diminished. This diminution is smaller when the Moon is at the edge of the penumbral cone. Totality of the Moon's eclipse never exceeds 1¾ hours. Moon loses heat and cools down more during an eclipse. During the totality period, the Moon is travelling through the width of the Earth. (The Sun moves about 2½' per hour.)

SOLAR ECLIPSE

The solar eclipse will occur when the Moon is in between the Earth and the Sun i.e.

(1) It will be an *amavasya*.

(2) The Moon must be on or near Rahu or Ketu so that its latitude is near zero and the three heavenly bodies, the Moon, the Earth and the Sun, are in a line.

The reasons for a solar eclipse are the same as for lunar eclipse i.e. the Sunrays should be stopped by the dark (non-luminous) Moon from falling on the Earth. It can happen only when the Moon comes in the line of the Sun and the Earth and in between them so that the rays can be stopped. The Earth and the Sun are on the ecliptic; so, the Moon should be either on the ecliptic or very near to it i.e. the Moon should be on either of its nodes (Rahu or Ketu) or near the same.

In the case of lunar eclipse, the Moon loses light when it enters umbra and the eclipse is visible alike to the whole part of the Earth which is facing the Moon. The Moon, being much smaller than the Earth, can obstruct the Sun's rays for a smaller area on the Earth and as such the eclipse is visible to a limited area of the Earth at a time.

Solar eclipse is of three kinds: (1) *total eclipse*, (2) *partial eclipse* and (3) *annular eclipse*.

In the total eclipse the whole of the Sun's disc is not seen by the observer while in the case of a partial eclipse only a part of the Sun's disc is covered by the Moon and as such cannot be seen.

The Moon's angular diameter varies from 33'31" to 29'22". The angular diameter is 29'22" when the Moon is at the greatest distance from the Earth i.e. at its apogee. The diameter is 33'31" when the Moon is nearest to the Earth i.e. at perigee. In the case of the Sun, the angular diameter of the Sun when at apogee is 31'32" and when at perigee it is 32'36".

By the above fact it can be noticed that if at the time of eclipse the Moon is nearest to the Earth and the Sun farthest, the Moon's apparent angular diameter will be greater than that of the Sun and it can hide the whole of Sun's disc from the observer on the Earth in the line of the Sun and the Moon. It will be a total eclipse for that observer.

In the case of partial eclipse, only a part of the Sun's disc will be hidden by the Moon. The reason being that the centres of the Sun and the Moon not being in an exact line with the observer i.e. when the Sun and the Moon are not exactly at Rahu or Ketu,

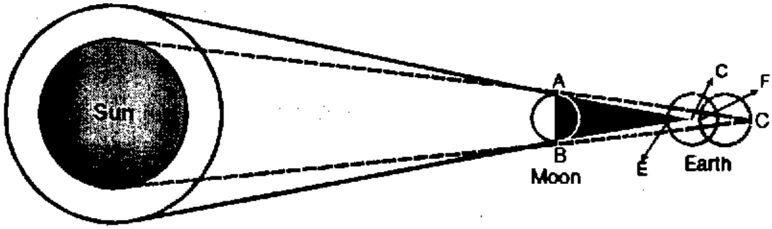


Figure 19

or the observer is at a point outside the umbral cone of the Moon.

The annular solar eclipse takes place when the Sun is the nearest to the Earth and the Moon is the farthest and other conditions remain the same as that of total eclipse. It will be an annular eclipse because in this case the Moon's apparent angular diameter is shorter than that of the Sun. The Moon's disc will not be able to fully cover the Sun's disc but will obscure only the central portion of the Sun. At the edges, the Sun is seen in this position in the form of a bright ring, as shown in figure 19.

The umbra created by the Moon is cone ABC when the observer is at E within umbra i.e. the Moon is the nearest and the Sun is the farthest. The observer thus can see the total solar eclipse. But when the observer is at F i.e. outside the umbra, which will happen when the Moon is the farthest from the Earth and the Sun is the nearest, he will not be observing the total eclipse and instead he will be able to see the Sun's disc like a ring. Only the shaded portion of the Sun will be hidden by the Moon and the rest i.e. circular ring will be visible over the entire hemisphere of the Earth. Further, the track of totality can never be more than 169 miles in width and the totality can never last more than eight minutes.

OCCULTATION

Moon's sidereal period of revolution is about $27^1/_3$ days and it moves eastwards with reference to the stars and at an average of more than half a degree per hour. In its movement, it continually interposes its disc between us and the stars. The sudden disappearance of a star by the Moon's disc is caslled the occultation of the star by the Moon.

Actually, the covering up of one celestial body by another is generally called occultation. Strictly speaking, the solar eclipse is also an occultation of the Sun by the Moon.

COMBUSTION

The planets are called combust when they are near the Sun in longitudes and their rays which are the reflection of the Sun's rays are intermingled with that of the Sun whose rays are much stronger. Therefor, the effect of the planets becomes much less. The planet under combustion is not visible, being too near the Sun, and is called *Asta*.

CHAPTER 8

Time

Mean Solar Day

We have seen that the Sun appears to describe an elliptical orbit around the Earth and its rate of change of direction in the orbit is not constant, i.e. the Sun appears to move somewhat non-uniformly in the zodiac. It moves faster when the Earth is at its perihelion, i.e. the nearest point from the Sun. Conversely the angular speed is slowest when the Earth is at aphelion point (the farthest from the Sun). The other factor is that the Sun appears to move in the ecliptic and not in the celestial equator, so its right ascension does not increase uniformly, it being measured along the celestial equator.

The apparent solar day is the interval elapsed between two successive transits of the Sun across the observer's meridian.

As the Sun's motion is not uniform throughout the year, the apparent solar days will be of different duration. It will be much troublesome in day-to-day working of the society. So, a fictitious body called the "mean Sun" was devised which is assumed to move on the celestial equator at a uniform rate. The

successive transits of this fictitious body or the mean Sun across the observer's meridian is defined as a mean solar day which is equal to the average daily motion of the real Sun in the ecliptic. The duration of such a mean solar day is divided into 24 hours. It implies that the right ascension of mean Sun increases at a uniform rate. When the mean Sun is at the meridian of a place, it is local mean noon there and the hour-angle of the mean Sun is zero. When the hour-angle of the mean Sun is 12 hours, it is said to be midnight there and this is the moment when the new civil day begins there.

The Local Mean Time

The time elapsed from the midnight of the place is known as local mean time. Thus LMT at midnight is zero hours. This is different from the hour-angle of the mean Sun.

The Earth is rotating from the west to east and it completes one rotation with respect to the Sun in one civil day. However, it completes one complete rotation with reference to any distant star in one sidereal day. Its spin in a sidereal day is 360°, while the same is about 361° for a civil day. A mean solar day is of 24 hours 3 minutes and 56.56 seconds in sidereal time. Mean sidereal day is equal to 24 hours, in sidereal hours, and is 23 hours 56 minutes 4.09 seconds in mean solar time. For simplicity, both solar day and sidereal day are taken as 24 hours in terms of their own hours. Thus, the Earth rotates 360° in 24 hours or, say, 1° in 4 minute. The places which are in the east will see the rising of the Sun early and those in the west will see it later. If the difference is 10° in terrestrial longitude, the difference in sunrise will be

of 10 × 4 = 40 minutes provided the terrestrial latitude is the same. This way, we can see that the local mean time of places at different terrestrial longitudes will be different in a country or a zone and the day-to-day work of the society will face a lot of trouble and practically be disrupted in the present era. The terrestrial latitudes and longitudes of Mumbai are 18°58' (N) and 72°50' (E), and of Calcutta 22°35' (N) an 88°23' (E).

The difference between latitudes is only 3°37' while in the longitudes it is 15°33', i.e. the difference between their local time will be of 15°33' × 4 = 62 minutes 12 seconds, i.e. 1 hour 2 minutes 12 seconds. The person at Mumbai will at his noon say that the time is 12 hours while at Calcutta he will say no, it is 1 hour 2 minutes 12 seconds p.m. and the schedule of railway timing, plane timing, radio, television, etc. will not be possible. So, a way was devised that within a country or a zone (in large countries), one standard meridian is fixed and the time of that meridian is taken as standard time for that country or the zone. It is called the standard time of a country or zonal standard time of that zone.

In India the standard meridian is having a longitude 82°30' (E) and this meridian passes through a place near Varanasi. The local mean time of this place is the Indian standard time and is followed throughout India.

Similarly, other countries or zones have also fixed their standard meridians. When going through the last few pages of the table of ascendents, it will be seen that the standard meridians of a country or a zone are fixed in such a way that normally the time

difference between that of Greenwich is a multiple of half an hour. The difference between the IST (Indian Standard Time) and that of the Greenwhich mean time is 5½ hours.

Units of Time

The following are the units of time as per *Surya Siddhanta*

6 pran	=	1 pal (also called vinadi)
60 pal	=	1 ghati (also called nadi)
60 ghati	=	1 day (Civil Day or solar day)
21,600 pran	=	1 day = 86,400 seconds

100 truti	=	1 tatpar
30 tatpar	=	1 nimesh
18 nimesh	=	1 kashtha
30 kashtha	=	1 kala
30 kala	=	1 ghatika
2 ghatika	=	1 muhurta
30 muhurta	=	1 day

The following are the units of time as prevalent during the modern time.

60 seconds	=	1 minute
60 minutes	=	1 hour
24 hours	=	1 day

In degrees and rashis

60" (seconds)	=	1' (minute)
60' (minute)	=	1° (degree)
30° (degree)	=	1 rashi (sign)
12 rashis	=	zodiac

Units of Measurement of Distances in Space

Three systems for measuring distance in space are in vogue.

(1) light year

(2) astronomical unit

(3) parsec

Light Year

Light travels at the rate of 1,86,000 miles (or 3,00,000 km) per second. The distance traversed by the light in one year is known as light year.

light year = 3,00,000 × 60 × 60 × 24 × 365.25 km.

So, one light year = 9.46×10^{12} km.

i.e. 9,460 billion kilometres or 5,880 billion miles.

Astronomical Unit

The semi-major axis of the Earth's orbit is known as astronomical unit. In other words, the half of maximum distance+ minimum distance of the Earth from the Sun is known as astronomical unit (AU).

One AU = 930 lakh miles

In other words, the distance between the Earth's

two positions at extreme points is two AUs. It can also be expressed as the mean distance of the Earth from the Sun.

Parsec

The distance corresponding to a parallax of 1" is called a parsec.

1 parsec = 2,06,265 astronomical units
= 3.26 light years
= 3.086×10^{13} km.

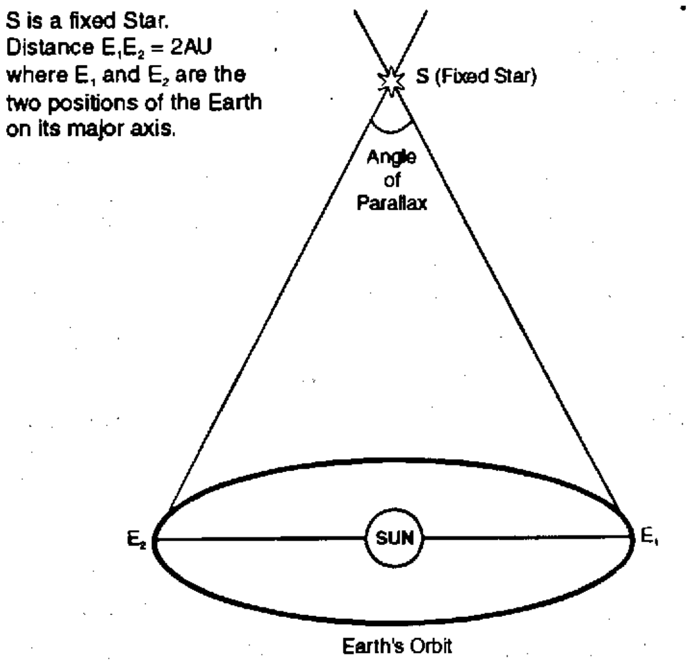


Figure 20

The distance is corresponding to a parallax of 1" and is inversely proportional to it. If the parallax is 0.001", the distance is 1000 parsecs and not 1/1000 parsec (see figure 19).

Civil Day

Nowadays, the time from one midnight to another midnight is a civil day. According to our ancient system, the time interval between one sunrise to another sunrise is called one 'savan day' i.e. civil day = 24 solar time hours.

Mean solar day = 24 hours 3 minutes 56.5 seconds in sidereal time hours, etc.

Sidereal Day

The time interval from one rising of a *nakshatra* to its rising next time is called a sidereal day or *nakshatra din*. It is of about 23 hours 56 minutes and 4 seconds in solar day hours.

Lunar Day or a Tithi

Lunar day or a tithi is the average time taken by the Moon from one tithi to the next tithi. Each tithi represents 12° phase difference between the Moon's position from the Sun's position, i.e. Moon's advancement over the Sun by another 12°. This average time is 23 hours 37 minutes 28 seconds.

MONTHS

Solar Month

When the centre of the Sun enters from one rashi to another, it is the *sankranti* of the other rashi. The time taken by the Sun from one *sankranti* to another is called a solar month. The time interval of every solar month differs because the angular velocity of the Sun is not uniform. When the angular velocity is more, the Sun crosses one rashi or sign early and that

solar month is smaller. Conversely, when the angular velocity of the Sun is less, the solar month is bigger. The average time of a solar month is 30.438 days.

Lunar Month

When the longitudes of the Sun and the Moon become exactly equal the *amavasya* ends. The period between the ending of one *amavasya* to the end of next *amavasya* is called a lunar month. It is also called the synodical month, i.e. 29.5306 mean solar days.

Anomalistic Month

The interval required by the Moon to move from perigee to perigee is called the anomalistic month. Its duration is 27.5546 mean solar days.

Nodical Month

The interval between two successive passages of the Moon through the ascending node is called a nodical month. It is of 27.2122 mean solar days. It is smaller than the sidereal month (27.32 days) because during a month's interval Rahu moves backwards on the zodiac towards the Moon.

YEARS

Astronomically, there are several kinds of 'years'.

The sidereal year is the true revolution period of the Earth around the Sun. It is of 365 days 6 hours 9 minutes 10 seconds, i.e. of 365.256 days.

The Tropical year is the period between two successive passages of the Sun across the first point Aries (Sayana). As the first point of Aries is not stationary, the tropical year is shorter by 20 minutes

from the sidereal year. Its duration is 365.242 days, i.e. 365 days 5 hours 48 minutes 45 seconds.

The calendar year is the mean length of the year. Its duration is 365.24 days, i.e. 365 days 5 hours 49 minutes 12 seconds.

The anomalistic year is the duration between two successive passages of the perihelion of the Earth. As the Earth's perihelion also moves about 11 seconds in its orbit every year and completes one revolution in about 108 thousand years, this year is slightly longer, i.e. of 365.26 days, or 365 days 6 hours 13 minutes and 53 seconds.

Lunar year: Twelve lunar months make a lunar year, i.e. of 12×29.5306 days = 354.3672 days approx.

Luni-Solar Year: Since early Vedic period, Indians followed solar year with lunar months and a synchronized luni-solar year. One system was prescribed in *Rigvedanga*, another in *Atharva-vedanga*. Varahamihira made some modifications for *adhik and kshya tithis* and *adhik maas*. The Luni-Solar year as at present used in our *panchangas*. Tithis of most of the religious and social festivals are based on a mixture of solar year and lunar months by the pandits. The months are the lunar months but every 19 years there is an increase of 7 months in this calendar (see page 55). The principal of making 13 months in a year is that if two times *amavasya* ends in a solar month, the month which followed the first *amavasya* will be repeated again after the second *amavasya,* i.e. there will be two lunar months of the same name. This name of two lunar months (for a particular solar month) will be after the name of the said solar month. This is in accordance with the

Moon's nakshatra on which the Moon was on the *poornima* day during the said solar month. This way, after every two to three years, we have a year of 13 lunar months and the difference between the solar and lunar years is adjusted.

CHAPTER 9

Panchanga

Panchanga is a Sanskrit word which consists of two words *pancha* + *anga*. *Pancha* means five and *anga* means parts or limbs. So, *panchanga* means five limbs.

These five limbs are:

(1) day

(2) tithi

(3) nakshatra (constellation)

(4) karna

(5) yoga

1. DAY

Day here is the weekday to decide the lordship of the concerned day. In the Indian astronomy the day is considered to be form sunrise to just before the next sunrise.

In the Western system, the name of the day is calculated easily from the dates of Gregorian calendar. The exact interval between the two successive vernal equinoxes, i.e. a tropical year, is 365

days 5 hours 48' and 45.3" or, say, 365.2422 days. When it is multiplied by 100, it gives 24.22 extra days (in excess of 365 days per year) in a century. So, Pope Gregory XIII adopted a calendar in 1582 according to which normally years will be of 365 days each but the years which are divisible by 4 without remainder, such as 1988, 1992, etc. will have 366 days, but the centuries, i.e. the year which are multiple of 100 but not multiple of 400 will only 365 days and the years which are multiple of 100 and also multiple of 400 will have 366 days.

Because there were 24.22 days extra in a century so 24 days have been added 4, 8 ,12 ... up to 96 and not 100; and $0.22 \times 4 = 0.88$, i.e. approximately 1 day has ben added in the 400 years.

In one year when $365 \div 7$ leaves a remainder of 1 so if the January 1, 1949 was Saturday, the January 1, 1950 will be one week day extra i.e. Sunday. In one century i.e. in 100 years the number of remaining days will be 100 + 24 leap days i.e. 124 extra days than complete weeks, which means ($124 \div 7$ leaving a remainder of 5) 5 extra days only after omitting complete weeks.

In 100 years (one century), the number of days more than the complete weeks = 5.

In 400 years (four centuries), the number of days more than the complete weeks = 20 + 1 as the 400th year is also a leap year = 21 which is divisible by 7. Thus, a period of four centuries folds up in complete weeks. This implies that the day on January 1, 1201 will be the same as on January 1, 801, or 1601, or 2001.

Example

The following is an illustration how to calculate the day of a week in Gregorian calendar which is presently in vogue.

To find out the day on March 4, 1988.

Number of days more than complete weeks in 1600 years	$= 0$	
Number of days more than complete weeks in 300 years	$= 5 \times 3 \div 7$, remainder =	1
Number of days more than complete weeks (as 87 years pass)	$= 87 \div 7$, remainder =	3
Leap days in 87 years	$= 21 \div 7$, remainder =	0
Number of days more than complete weeks in January 88	$= 31 \div 7$, remainder =	3
Number of days more than complete weeks in February 88	$= 29 \div 7$, remainder =	1
Number of days more than complete weeks in March 88	$= 4 \div 7$, remainder =	4
Total		= 12

Now, $12 \div 7$ leaves the remainder 5.

Now count it Monday if the remainder is 1, Tuesday if it is 2, Wednesday if 3, Thursday if 4, Friday if 5, Saturday if 6, and Sunday if 0 or 7.

The day on March 4, 1988 is thus Friday as the remainder is 5.

2. TITHI

A lunar month is from the end of one *amavasya*

to the end of succeeding *amavasya*, i.e. the difference between the longitudes of the Moon and the Sun start incresing. As there are 360° in the zodiac, so in a lunar month the Moon moves 360° more than that of the Sun. There are 30 tithis in one lunar month.

$$\text{So, one tithi} = \frac{360^\circ}{30} = 12^\circ$$

The following table shows the tithis and the difference of the longitudes of the Moon and the Sun.

Shukla Paksha (Bright Half)

Name	Tithi No.	Longitude of Moon — Sun
Pratipada	1	0° to 12°
Dviteeya	2	12° to 24°
Triteeya	3	24° to 36°
Chaturthi	4	36° to 48°
Panchami	5	48° to 60°
Shashthi	6	60° to 72°
Saptami	7	72° to 84°
Ashtami	8	84° to 96°
Navami	9	96° to 108°
Dashami	10	108° to 120°
Ekadashi	11	120° to 132°
Dwadashi	12	132° to 144°
Trayodashi	13	144° to 156°
Chaturdashi	14	156° to 168°
Poornima (Full Moon)	15	168° to 180°

Krishna Paksha (Dark Half)

Name	Tithi No.	Longitude of Moon — Sun
Pratipada	16	180° to 192°
Dviteeya	17	192° to 204°
Triteeya	18	204° to 216°
Chaturthi	19	216° to 228°
Panchami	20	228° to 240°
Shashthi	21	240° to 252°
Saptami	22	252° to 264°
Ashtami	23	264° to 276°
Navami	24	276° to 288°
Dashami	25	288° to 300°
Ekadashi	26	300° to 312°
Dwadashi	27	312° to 324°
Trayodasi	28	324° to 336°
Chaturdashi	29	336° to 348°
Amavasya (New Moon)	30	348° to 360°

The 1st *tithi* starts when the Moon starts moving ahead of the Sun, i.e. more than 0° difference. When the differnce becomes just more than 12°, the *tithi* becomes Dviteeya. Similarly, it is for other tithis.

The above is the scheme for the tithis but these 30 tihtis falls in approximately 29.5 days and not in 30 days. The Moon moves sometimes fast, i.e. about 15° in 24 hours and sometimes slow, about 12° in 24 hours. Tithis are depending upon the net difference of motion of the Sun and the Moon. Their individual

motions depend upon their distances from apogee or perigee.

This fast and slow movement of the Moon causes sometimes the losing of a tithi and sometimes gaining a tithi. The principle behind it in the Indian lunar calendar is that the tithi which is at the time of sunrise is the tithi of the day. Whether that tithi may remain for a few minutes in that day or it may prolong upto the next sunrise. A tithi which starts after sunrise and ends before the next Sun rise is said to be missed in that fortnight. If a tithi which starts just before sunrise and ends after the next sunrise will be having two days in its name in that fortnight. The system was introduced for day-to-day working of the society.

The formula for the calculation of tithi:

$$\frac{\text{Longitude of the Moon} - \text{Longitude of the Sun}}{12^\circ}$$

Example

Calculate tithi at 11.30 a.m. on October 12, 2000

	Sun's Longitude	Moon's Longitude
On Oct. 13, 2000 at 5.30 a.m.	$7^s 27^\circ 25'$	$2^s 19^\circ 56'$
On Oct. 13, 2000 at 5.30 a.m.	$7^s 26^\circ 24'$ 'A'	$2^s 5^\circ 1'$ 'A'
Difference for 24 hours	$1^\circ 1'$	$14^\circ 55'$
Difference for 6 hours	$15'$ 'B'	$3^\circ 44'$ 'B'
Longitude at $11^h.30'$ a.m. (A + B)	$7^s 26^\circ 39'$	$2^s 8^\circ 45'$
As one sign = 30°, so	$236^\circ 39'$	$68^\circ 45'$

By the above formula, $\frac{68^\circ\ 45' - 236^\circ\ 39'}{12}$

As 68° 45' is less than 236° 39', add 360° in 68° 45'

$$\frac{428^\circ\ 45' - 236^\circ\ 39'}{12} = \frac{192^\circ\ 6'}{12}$$

$$= 16\frac{0^\circ\ 6'}{12}$$

which shows that 16 tithis have passed and the 17th is running at that time and its 0° 6' have passed out of 12°.

The tithis at a particular moment are calculated in the above manner.

Now you will see how the tithis last for two days or are missed. The principle behind it is that for social purposes the tithi of a day is the tithi which is at the time of the sunrise on that day. It should be remembered that it is for social purposes and it does not mean that tithi will in reality remain for the whole of day.

Examples

How a tithi is missed or *tithi kshaya*.

Two such examples are given below:

(1) Take the case of October 18, 2000 and of October 19, 2000.

Sunrise at Delhi on October 18 is at $6^h 28'$ a.m.

Tithi on October 18, 2000 is calculated as under:

Tithi =

$$\frac{\text{Longitude of the Moon} - \text{Longitude of the Sun}}{12^\circ}$$

$$\text{Tithi} = \frac{2^s\ 1^\circ\ 4' - 6^s\ 1^\circ\ 5'}{12}$$

$$= \frac{61^\circ\ 4' - 181^\circ\ 5'}{12}$$

As 61 is shorter than 181, add 360 in 61.

$$\text{Tithi} = \frac{61^\circ\ 4' + 360^\circ - 181^\circ\ 5'}{12}$$

$$= \frac{239^\circ\ 59'}{12} = 19\frac{11^\circ\ 59'}{12}$$

It shows that 19 tithis have passed and 20th is running. So, the tithi of October 18, 2000 will be called ***krishna paksha panchmi.***

Tithi on October 19, 2000 is calculated below. sunrise at Delhi on that day is at $6^h\ 28'$ a.m.

$$\text{Tithi} = \frac{2^s\ 15^\circ\ 9' - 6^s\ 2^\circ\ 5'}{12}$$

$$= \frac{75^\circ\ 9' - 182^\circ\ 5'}{12}$$

$$= \frac{75^\circ\ 9' + 360^\circ - 182^\circ\ 5'}{12}$$

$$= \frac{253^\circ\ 4'}{12} = 21\frac{1^\circ\ 4'}{12}$$ which shows 22nd

tithi is running on 19th October.

Hence, the tithi on October 19, 2000 is *Krishna Paksha Saptami.*

It is seen that 21st tithi has been missed.

(2) Take another case of missing tithi, i.e. of February 2, 2001 and February 3, 2001.

Sunrise at Delhi on 2nd February is at 7.13 a.m.

Sunrise at Delhi on 3rd February is at 7.12 a.m.

Calculation of tithi on 2nd February:

Tithi =

$$\frac{\text{Longitude of the Moon} - \text{Longitude of the Sun}}{12^\circ}$$

$$= \frac{0^s\ 25^\circ\ 21' - 9^s\ 19^\circ\ 24'}{12}$$

$$= \frac{25^\circ\ 21' - 289^\circ\ 24'}{12}$$

$$= \frac{25^\circ\ 21' + 360 - 289^\circ\ 24'}{12}$$

$$= \frac{95^\circ\ 57'}{12} = 7\frac{11^\circ\ 57'}{12}$$

Saptami has passed and *Shukla Paksha Ashtami* is running.

Calculation of tithi on 3rd February:

$$\text{Tithi} = \frac{1^s\ 8^\circ\ 50' - 9^s\ 20^\circ\ 25'}{12}$$

$$= \frac{38° \; 50' - 290° \; 25'}{12}$$

$$= \frac{108° \; 25'}{12} = 9\frac{0° \; 25'}{12}$$

Nine tithis have passed and tenth is running. So tithi on February 3rd, 2001 is *Shukla Paksha Dashami.* It may be seen that Navami has been missed.

Example of Adhik Tithi

(3) Take the case of October 6, 2000 and October 7, 2000.

Sunrise at Delhi on October 6, 2000 and October 7, 2000 is at 6.21 a.m.

Tithi calculation on October 6, 2000 is as under:

$$\text{Tithi} = \frac{8^s \; 25° \; 28' - 5^s \; 19° \; 13'}{12}$$

$$= \frac{265° \; 28' - 169° \; 13'}{12}$$

$$= \frac{96° \; 15'}{12} = 8\frac{0° \; 15'}{12}$$

Eighth tithi has passed and ninth is running. So, the tithi of October 6, 2000 will be called *Shukla Paksha Navami.*

Tithi on October 7, 2000 is calculated as under:

$$\text{Tithi} = \frac{9^s \; 7° \; 16' - 5^s \; 20° \; 12'}{12}$$

$$= \frac{277^\circ\ 16' - 170^\circ\ 12'}{12}$$

$$= \frac{107^\circ\ 4'}{12} = 8\frac{11^\circ\ 4'}{12}$$

Eight tithies have passed and 9th is running at the time of Sunrise. Hence, the tithi of October 7, 2000 is Shukla Paksha Navami. By this it is seen that the tithi for October 6, 2000 and October 7, 2000 is Navami for both the days.

(4) Calculation of tithies on January 31, 2001 and February 1, 2001 are given below.

Tithi of 31st January, 2001

$$\text{Tithi} = \frac{11^s\ 29^\circ\ 27' - 9^s\ 17^\circ\ 22'}{12}$$

$$= \frac{359^\circ\ 27' - 287^\circ\ 22'}{12}$$

$$= \frac{72^\circ\ 5'}{12} = 6\frac{0^\circ\ 5'}{12}$$

i.e. *Shukla Paksha Saptami*

Tithi on February 1, 2001

$$\text{Tithi} = \frac{0^s\ 12^\circ\ 13' - 9^s\ 18^\circ\ 23'}{12}$$

$$= \frac{12^\circ\ 13' - 288^\circ\ 23'}{12}$$

$$= \frac{12^\circ\ 13' + 360^\circ - 288^\circ\ 23'}{12}$$

$$= \frac{372^\circ\ 13' - 288^\circ\ 23'}{12}$$

$$= \frac{83^\circ\ 50'}{12} = 6\frac{11^\circ\ 50'}{12}$$

which shows that *Shukla Paksha Saptmi* is running at Sunrise of February 1, 2001.

So, *Shukla Paksha Saptmi* is for two days, namely, January 31, 2001 and February 1, 2001.

3. NAKSHATRA

The division of the zodiac in 27 nakshatras has been shown at in chapter 5. However, the calculations for finding out the number of nakshatras is as under:

The 27 nakshatras are in 360°

$$\text{So, one nakshatra} = \frac{360^\circ}{27}$$

$$= 13^\circ\frac{1}{3}, \text{ i.e. } 13^\circ 20'$$

Example

Now, we have to find the nakshatra of the Moon whose longitude is, say, 245°16'.

The nakshatra number will be arrived at

$$= \frac{245^\circ\ 16'}{13^\circ\ 20'}$$

$$= \frac{(245 \times 60 + 16)'}{(13 \times 60 + 20)'}$$

$$= \frac{14700' + 16'}{780' + 20'}$$

$$= \frac{14716'}{800'} = 18\frac{316'}{800'}$$

i.e. the 2nd quarter, or pada, or charan of 19th nakshatra (Mula nakshatra).

If the remainder is from 1' to 200' it is 1st quarter; if it is 201' to 400' it is 2nd quarter; if it is 401' to 600' it is 3rd quarter; if it is 601' to 800' it is 4th quarter.

Names of Nakshatras

(1) Ashwini	(2) Bharani
(3) Krittika	(4) Rohini
(5) Mrigashirsha	(6) Ardra
(7) Punarvasu	(8) Pushya
(9) Ashlesha	(10) Magha
(11) Purvaphalguni	(12) Uttaraphalguni
(13) Hasta	(14) Chitra
(15) Swati	(16) Vishakha
(17) Anuradha	(18) Jyeshtha
(19) Mula	(20) Purvashadha
(21) Uttarashadha	(22) Shravana
(23) Dhanistha	(24) Satabhisha
(25) Purvabhadrapada	(26) Uttarabhadrapada
(27) Revati	

This way by changing the signs and degrees into minutes and dividing by 800', the quotient gives the number of nakshatras passed and the remainder gives the minutes of the next nakshatra which has passed out of 800'.

In the above manner, we can calculate the nakshatra of any planet at any moment, provided the *Nirayana* longitudes are known.

But, when we say what nakshatra is running at present, the reference in *Panchanga* is always to the Moon's nakshatra which is required for *dashaphal* as well as *muhurta*.

4. KARANA

In each tithi there are two karanas. The first Karana ends at the middle of the tithi and the second ends with the ending of the tithi. The two halves are not obtained by dividing the time of the tithi in two halves. Each Karana is decided by the time taken by the Moon to gain over the Sun by a margin of 6° (as against 12° in the case of a tithi).

The method of calculating the tithi is:

Tithi =

$$\frac{\text{Longitude of the Moon} - \text{Longitude of the Sun}}{12^\circ}$$

Quotient + 1 gives the Tithi.

The formula for calculating Karana is:

Karana =

$$\frac{\text{Longitude of the Moon} - \text{Longitude of the Sun}}{6^\circ}$$

The quotient + 1 will give the number of Karanas running.

Names of Karanas

1. Bava
2. Balava
3. Kaulava
4. Taitila
5. Gara
6. Vanij
7. Vishti

which repeat eight times, i.e. $7 \times 8 = 56$ such Karanas plus four others, namely,

i) Shakuni

ii) Chatushpada

iii) Naga

iv) Kintughna

Making a total of $56 + 4 = 60$ Karanas in 30 tithis.

In other words, there are eleven different Karanas: 4 non-recurring and seven recurring 8 times during a lunar month. Alll these 11 Karanas have distinctive characterstics attached to them. Some Karanas like Vishti (Bhadra), Shakuni, Chatuspada, Naga, Kintughna are inauspicious and some are good for muhurta of various rituals, ceremonies, etc.

Example

Take the case of October 18, 2000 at 6.25 a.m. (given in this chapter in the example of missing tithi at page .)

Karana =

$$\frac{\text{Longitude of the Moon} - \text{Longitude of the Sun}}{6^\circ}$$

$$\text{Karana} = \frac{2^s\ 1^\circ\ 4' - 6^s\ 1^\circ\ 5'}{6}$$

$$= \frac{61^\circ\ 4' - 181^\circ\ 5'}{6}$$

As the longitude of the Moon is less than the longitude to the Sun, add 360° to the longitude of the Moon.

$$= \frac{421^\circ\ 4' - 181^\circ\ 5'}{6}$$

$$= \frac{239^\circ\ 59'}{6}$$

$$= 39\frac{5^\circ\ 59'}{6}$$

i.e. 40th Karana was running or the 2nd Karana of 20th tithi (40 ÷ 2) was running. The table shows that the 2nd Karana of 20th is 4th Karana, i.e. Taitila.

Tithi	1st Karana	2nd Karana	Tithi	1st Karana	2nd Karana
1	Kintughna	1	16	2	3
2	2	3	17	4	5
3	4	5	18	6	7
4	6	7	19	1	2
5	1	2	20	3	4

Tithi	1st Karana	2nd Karana	Tithi	1st Karana	2nd Karana
6	3	4	21	5	6
7	5	6	22	7	1
8	7	1	23	2	3
9	2	3	24	4	5
10	4	5	25	6	7
11	6	7	26	1	2
12	1	2	27	3	4
13	3	4	28	5	6
14	5	6	29	7	Shakuni
15	7	1	30	Chatushpada	Naga

5. YOGA

Yogas are the result of combined movement of the Sun and the Moon. These can be inauspicious or auspicious for arriving at proper *muhurta*.

Names of Yogas

1. Vishakumbha
2. Priti
3. Ayushman
4. Saubhagya
5. Shobhana
6. Atiganda
7. Sukarma
8. Dhriti
9. Shula
10. Ganda
11. Vridhi
12. Dhruva
13. Vyaghata
14. Harshana
15. Vajra
16. Siddhi
17. Vyatipata
18. Variyan
19. Prigha
20. Shiva

21. Siddha
22. Sadhya
23. Shubha
24. Shukla (Shukra)
25. Brahma
26. Indra
27. Vaidhriti

The names of *yogas* themselves indicate (from their word meaning) where these are auspicious (good) and were these are inauspicious (bad).

So, each *yoga* $= \dfrac{360^\circ}{27} = 13^\circ 20' = 800'$

The formula for calculating yoga:

Yoga =

$$\frac{\text{Long. of the Sun + Long. of the Moon (in minutes)}}{800'}$$

Example

Any moment for which the yoga is to be found out, say, for example, Sun's longitude be $9^s\,3^\circ\,23'$ and Moon's longitude be $2^s\,6^\circ\,36'$ (January 18, 1992 at 5.30 a.m.)

Yoga at that time tithi $= \dfrac{9^s\,3^\circ\,23' + 2^s\,\,6^\circ\,36'}{800'}$

$$= \frac{\left[(9^s \times 30) + 3^\circ\right] \times 60 + 23' + \left[(2^s \times 30) + 6^\circ\right] \times 60 + 36'}{800'}$$

$$= \frac{16403' + 3996'}{800'}$$

$$= \frac{20399'}{800'}$$

$$= 25\frac{399'}{800'}$$

25th yoga has passed and 26th yoga, i.e. Indra was running at that time.

CHAPTER **10**

Upagrahas and Stars

UPAGRAHAS (astronomical points on the ecliptic)

These are secondary planets (upagrahas in Indian astronomy). Of course, there are tertiary planets also. The secondary and the tertiary planets are invisible (not physical bodies). Actually, these so, called planets are astrologically sensitive points, mathematically computed positions with reference to the Sun's longitude. These points are of considerable importance with the birth chart as well as in the progressed horoscope of the individual (or a nation).

These *upagrahas* are Dhuma, Paridhi, Indrachapa and Sikhi. The method of calculation from the Sun's position is given below:

1. Dhuma	:	Sun's Nirayana longitude (S)	
		+ 133°20'	or 133°20' + S
		(10 nakshatras ahead of the Sun)	
2. Patha	:	360° – Dhuma	or 226°40' – S
3. Paridhi	:	Patha + 180°	or 46°40' – S
4. Indrachapa	:	360° – Paridhi	or 313°20' + S

5. Sikhi : Indrachapa + 16°40' or 330° + S

Example

Presume that, in a horoscope the Sun's location is at 12° in Gemini.

So, the Sun's longitude = 72° ... (S)

1. Dhuma : 72° + 133°20' = 205°20'
   (133°20' + 72° = 205°20')
2. Patha : 360° – 205°20' = 154°40'
   (226°40' – 72° = 154°40')
3. Paridhi : 154°40' + 180° = 334°40'
   (46°40' – 72° = 334°40')
4. Indrachapa : 360° – 334°40' = 25°20'
   (313°20' + 72° = 25°20')
5. Sikhi : 25°20' + 16°40' = 42°
   (330° + 72° = 42°)

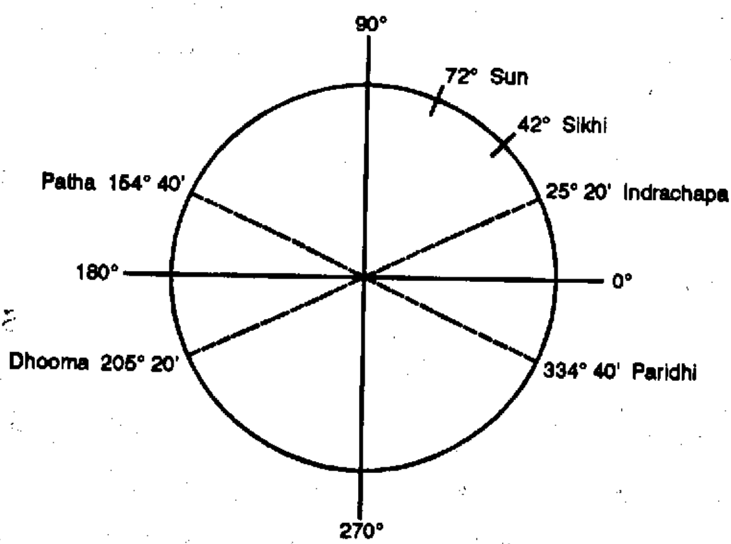


Figure 21

The above sensitive points calculated with reference to the Sun's longitude serve as Amshas of planets Mars (for Dhooma), Rahu (for Patha), Moon (for Paridhi), Venus (for Indrachap), and Ketu (for Sikhi or upaketu). But for calculating the position of upagrahas of the other four planets - the Sun, Mercury, Jupiter and Saturn, other methods are used.

Upagrahas (Astrological)

Astrologically speaking (not astronomically), there are nine upagrahas relating to the nine grahas. They are considered their (adverse) Amsha.

Upagrahas:

	Kala	**Paridhi** or Parivesh	**Dhoom**
Amsha of:	*Sun*	*Moon*	*Mars*

	Ardhyam or Ardhaprahara	**Yama-gantak**	**Indrachapa** or Kodanda
Amsha of:	*Mercury*	*Jupiter*	*Venus*

	Gulika or Mandi	**Patha** or Vyatipata	**Sikhi** or Upaketu
Amsha of:	*Saturn*	*Rahu*	*Ketu*

The calculation procedure followed for the upagrahas, Ardhyam, Yamagantak and Mandi (or Gulika) is as follows:

Birth During Day

Divide the daytime (dinamaan) into eight equal parts. Alloted to the various weekdays, the first belonging to the planet ruling the weekday - the first seven in the weekday's cyclic order, eighth always called *nireesh,* i.e. without lordship.

Birth During Night

Divide the night span (*ratrimaan*) also into eight equal parts. Allot the first part to the lordship of the fifth upagraha (in the cyclic order) from the lord (planet) of the day. Eighth part will be Nireesh.

Thus, on Sunday: It is Yamagantak (the first part of the night), followed by Kodanda, Gulika, Kala, Paridhi, Dhooma, Ardhyam and, lastly, the unalloted. We have to calculate the ascendant at the commencement of each period of upagraha and that will give the longitude of the related upagraha.

STARS

Stars are self-luminous gaseous bodies in the celestial sphere. They are grouped into constellations (conspicuous grouping forming a small solid angle, with the Earth as the apex). The most conspicuous stars in a constellation are given a Greek letter ('α' being the brightest), but in ancient Indian astronomy, the nakshatra is named after the brightest or most conspicuous star (such as Rohini or Chitra, etc.). Some stars have their own names (like Spica, Anteres, Polaris, Arcturus, Sirius, etc.).

The nearest star to our Solar System is Proxima Centauri but even its distance is very great, i.e. 4.2 light-years. Sirius (Lubdhaka), the brightest star in the sky, is 8.7 light-years away (Sirius is in constellation Canis Majoris). Arcturus (Swati) in Bootes is 36 light-years away. Anteres (Jyeshtha) in Scorpio is a red star, which is 330 light-years away. Betelguese (Ardra) in Orion is at 310 light-years. Regulus (Magha) α - Leonis in Leo is 425 light-years from us. A light-year is 5,880 billion miles.

No telescope, however strong in magnification, will show a star as a measurable disc. We have, therefore, to depend upon the astro-spectroscope. Stars have great range in luminosity and temperature.

The main sequence stars (such as the Sun) are classified as dwarfs. Then there are the giant branch, and white dwarfs, neutron stars and black holes.

The usual sequences are like this:

From Nebulus, mass of 1 solar mass, a main sequnece star exists for 10 billion Solar Years, often it expands into a red giant branch and then coalesces into a white dwarf. A star of higher mass (10 solar mass) carries on for main sequence life of a million years, becomes a red giant, explodes as a supernova and then becomes a neutron star. A star of still higher mass (10 to 30 solar mass) has a main sequence life of a million years, becomes a red giant and then collapses into an extremely dense mass forming a black hole, from which even light cannot escape. (Main sequence stars with hot white or bluish stars, i.e. types O and B and end with feeble red stars, i.e. type M. The Sun is a yellow dwarf star of type G.)

Mean Places of Stars *

S. No.	Star	Indian Name	Nirayana Longitude	Magni-tude	Distance Light Yrs.
1.	β Arietis	Ashwini	Aries 10°6'	2.72	
2.	41 Arieties	Bharani	Aries 24°20'	3.68	
3.	Alcyone -2 (η Tauri)	Krittika	Taurus 6°8'	2.96	.
4.	Aldebaran (α Tauri)	Rohini	Taurus 15°55'	1.06	68.0
5.	Capella (α Aurigae)	Brahmahrd	Taurus 28°0'	0.21	
6.	β Tauri	Agni	Taurus 28°43'	1.78	
7.	λ Orionis (1)	Mrigashirsa	Taurus 29°50'	3.66	
8.	Polaris	Dhruva	Gemini 4°42'	2.1v	680
9.	Betelguese (α Orionis)	Ardra	Gemini 4°53'	0.6v	310
10.	Sirius (α Canis Majoris)	Lubdhaka	Gemini 20°13'	-1.58	8.7
11.	Canopus (α Carinae)	Agastya	Gemini 21°06'	-0.86	1200
12.	Pollux (β Geminorum)	Punarvasu	Gemini 29°21'	1.21	36
13.	δ Cancri	Pushya	Cancer 14°51'	4.17	
14.	epsilon ε Hydrae	Ashlesha	Cancer 18°29'	3.48	
15.	Dubhe (α Ursae Majoris)	Kratu	Cancer 21°20'	1.95	75
16.	Regulus (α Leonis)	Magha	Leo 5°58'	1.34	425
17.	δ Leonis delta	P. Phalguni	Leo 17°27'	2.58	
18.	Denebola (β Leonis)	U. Phalguni	Leo 27°45'	2.23	

Star	Indian Name	Nirayana Longitude	Magni-tude	Distance Light Yrs.
19. δ Corvi delta	Hasta	Virgo 19°35	3.11	
20. Spica (α Virginis)	Chitra	Virgo 29°59'	1.21	260
21. Arcturus (α Bootis)	Swati	Libra 0°22'	0.24	36
22. α Libra	Vishakha	Libra 21°13'	2.90	330
23. β Centauri		Libra 29°56'	0.86	4.2
24. α Centauri		Scorpio 5°38'	0.06	4.3
25. δ Scorpii	Anuradha	Scorpio 8°42'	2.54	
26. Antares (α Scorpii)	Jyeshtha	Scorpio 15°54'	1.2v	330
27. λ Scorpii	Mula	Sagittarius 0°43'	1.71	
28. δ Sagittarii	P. Ashadha	Sagittarius10°43'	2.84	
29. σ Sagittarii	U. Ashadha	Sagittarius18°31'	2.14	
30. Vega (α Lyrae)	Abhijit	Sagittarius 21°27'	0.14	26
31. Altair (α Aquilae)	Shravana	Capricorn 7°55'	0.89	16.6
32. β Delphini	Dhanishta	Capricorn 22°29'	3.72	
33. λ Aquarii	Satabhisha	Aquarius 17°43'	3.84	
34. Markab (α Pegasi)	P. Bhadra-pada	Aquarius 29°37'	2.57	beta!
35. y Pegasi	U. Bhadra-	Pisces 15°17'	2.87	gamma!
36. ξ Piscium	Revati	Pisces 26°01'	5.57	Zeta

*on January 1, 1991. Tropical Longitude = Nirayana Longitude + 23°43'53"

HR diagram is prepared by plotting surface temperature from 3,000°C to 40,000°C, against luminosity (Sun = 1), varying up to 1,00,000 times that of the Sun. For the main sequence stars, the

luminosity, increases proportionally (in a logarithmic scale) to surface temperature. But for some luminosity is high though surface temperature is comparatively low (like Betelguese, Antares) while for others (like Sirius, Procyon B) luminosity is low even with high surface temperature. Stars like Betelguese (supergiants) are well advanced in their evolution. W-type stars have surface temperatures, of up to 80,000°C, and have bright lines (nitrogen, calcium, etc.) in spectra. Highly luminous Spica (Chitra) is B type star with helium lines dominant. Siriys (Lubdhaka) is a type (temperature 10,000°C) with calcium lines dominating. G type (Capella and the Sun) both giants and dwarfs, with surface temperature 5,000°C - 6,000°C have numerous metallic lines. Arcturus (Swati) is a K-giant type temprature with weak hydrogen lines and strong metalic lines. Betelguese (Ardra) is M-giant type with surface temperature 3,000°C - 3,400°C, having complicated spectra with many bands. S type (X Cygni) have prominent bands of titanium oxide and zirconium oxides.

The source of stellar energy is nuclear reactions, mainly four hydrogen nuclei being merged to form a helium nucleus. In this nuclear reaction, the Sun is losing its mass (converted to energy) at the rate of four million tons per second. Still, it will last, in the present from, for 5 billion years more.

COMETS

Members of the Solar System, move round the Sun in an orbit much more elliptical than that of a planet. A large comet is made up of small solid particles surrounded by an envelope of tenuous gas.

The tail of a comet consists of excessively rarefied gas and a fine dust released by star heat and generally points away from the Sun due to solar wind and solar radiation pressure. There are manyshort period comets with periods of a few years, but these are very dim. The only bright comet of a period less than a century is the Hailey's comet (its period is about 76 years). It was last seen in 1986. Comets are seen by reflected light of the Sun when they are near enough and in a position to be seen.

THE GALAXY

The Galaxy is a huge star system of which the Sun is a memeber. It is seen in the sky as the Milky Way. It consists of about 100,000 million stars and gaseous nebula. Herschel, more than a century and a half ago, was the first to postulate the shape of the Galaxy, – i.e. like a double convex lens, with diameter of 100,000 light-years and thickness of 10,000 light-years. The Sun lies at a distance of 25,000 to 30,000 light-years from the galactic nucleus (which is placed beyond the star clouds in the constellation of Sagittarius).

The Galaxy is a spiral and is in rotation round its nucleus. The Sun takes some 225 million years to complete its rotation in the Galaxy. The great spiral is Andromeda, a member of local group of galaxy, and is larger than the Galaxy.

EXTRA GALACTIC NEBULAE

Extra galactic nebulae are the separate stellar systems lying far beyond the Galaxy. Only three are visible to the naked eye. Two Magallenic Clouds and the Adromeda spiral. The Megallanic clouds are

200,000 light-years away.

The most distant galaxy observed is 3C-295 in the 'Bootes', and is estimated to be 5000 million light-years away. The galaxies are expanding with red shift in spectra.

CHAPTER 11

Rising and Setting

Two types of motion of planets with respect to the Earth are generally considered.

(1) Diurnal motion.

(2) Longitudinal motion.

1 DIURNAL MOTION

The earth rotates around its axis from west to east in 24 hours or, approximately, a day. Due to this rotation an observer on the Earth sees the Sun and other heavenly bodies moving from east to west. This apparent west-ward rotation of heavenly bodies is called their diurnal motion.

due to this motion, the heavenly bodies appear to rise in the east and set in the west.

In figure 23, N E S W is the celestial horizon (where N is for north, E is for east, S is for south and W is for west) of an observer at O. P and Q are poles of the celestial equator. Star X appears moving in the direction shown by the arrows, meeting the horizon at B while going down, and meeting at A while cm-ing up. The star is rising when it is coming up the

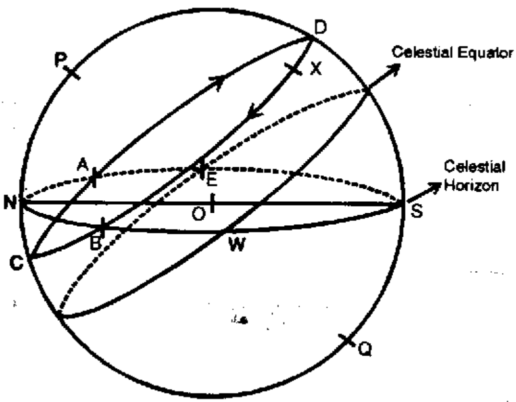


Figure 23

horizon at A and remains visible to the observer during its course from A to B. At B, it culminat at D as its altitude is the highest and after that it starts declining and goes down the horizon and cannot be seen by the observer. So, it is said to be setting and remains set from B to C and then to A. It is the rising and setting once in a day or, say, in one rotation of the Earth. This rising and setting is like that of the Sun. In this case, there is no change of longitudes as in the case of fixed stars.

2 LONGITUDINAL MOTION

The planets, the Sun and the Moon have little change in their longitudes due to their revolution in the zodiac. In astrology, the meaning of rising and setting of planets including the Sun and the Moon is different from that as explained above. In astrology, when a planet cannot be seen by naked eye due to its nearness to the Sun, it is said to have set or combust. The same becomes invisible on account of dazzling light of the Sun. It is well known that Sun is the source of light in the solar system and other planets simply reflect the light received from the Sun. In case the planet moves a certain distance away from the Sun, it becomes visible and is said to have risen.

सूर्यादभ्यधिकाः पश्चादस्तं जीवकुजार्कजाः ।
ऊनाः प्रागुदयं यान्ति शुक्रजौ वक्रिणौ तथा ।।२।।
ऊनाः विवस्वतः प्राच्यामस्तं चंद्रशभार्गवाः ।
व्रजन्त्यभ्यधिकाः पश्चादुदयं शीघ्र यायिनः ।।३।।
(सूर्य सिद्धान्त–उदयास्ताधिकार)

There are two types of planets, namely, (a) outer planets (Saturn, Jupiter and Mars) whose orbits are larger than the Earth and whose sidereal period is also greater, i.e. their angular velocity is shorter than the Earth, in other words, it can be said that the Sun moves faster than outer planets. (b) Inner planets (Venus, Mercury, Moon and can also be included in this category) as they move faster than the Sun. The paths of Venus and Mercury are shorter than that of the Earth. The Moon revolves round the Earth and their sidereal period is shorter than that of the Sun.

COMBUSTION OF OUTER PLANETS

(i) As the Sun moves faster than the outer planets, viz., Saturn, Jupiter and Mars, it appears to be moving towards them. In such a case, their longitudes are more than the Sun. They are seen in the western sky after sunset. After some days when the Sun comes nearer to these planets, they are invisible by naked eye and are said to have set or combust. After some time, the Sun is in conjunction with them i.e. they are in a position of deep combust. The Sun starts moving ahead of them. When it goes ahead by a certain distance, outer planets are visible in the east before the sunrise and are said to be rising in the east.

Let us now see the direction of movement of planets and zodiac. Since the Earth rotates from west to east, all the planets including the zodiac appear to move from east to west. The position (the sign) of zodiac which is rising in the east at any movement is called ascendant. At the time of sunrise. Let the longitude of the Sun be 15° Aries. At mid-noon, the Sun will be in the mid-heaven. So the Ascendant at that time may be 15° Cancer approximately. At the time of sunset the longitudes of the Sun will be roughly 15°30' Aries. It shows that the zodiac from east to west and completes one round daily.

It shows that the longitudes are increasing in the direction from west to south to east to north i.e. in the direction in which the Earth is rotating.

(*ii*) Moon is never retrograde as it is revolving around the Earth. It moves much faster than the Sun and when reaches near it is seen in the west and becomes invisible in the east. Helical setting of the Moon takes place once in a month. It sets in east on *krishana paksha chaturdashi* i.e. it becomes combust and rises in the west after *shukla paksha pratipada*.

उदयास्त विधिः प्राग्वत्कर्तव्यः शीतगोरपि ।
भागैद्वादिशभिः पश्चाद् दृश्यः प्राग्यात्यदृश्यतामा ।
(सूर्य सिद्धांत श्रृङ्गोभत्यधिकार)

When the Moon is within 12° of the Sun it is not seen by naked eye i.e. it becomes combust.

COMBUSTION OF INNER PLANETS

Mercury and Venus do not remain direct and become retrograde when they come near the Earth. Their motion is faster than the Sun. When they are direct and their longitudes are less than the Sun, they are visible in the east before the sunrise. Due to their faster motion after some days, they reach near the Sun and cannot be seen; they become combust. When they move sufficiently ahead of the Sun and their longitudes are more than the Sun by a certain amount, they become visible in the west after the sunset. Mercury and Venus do not remain direct and become retrograde when they are near the Earth as their motion is faster than of the Sun.

When the longitudes of retrograde Mercury and Venus are more than the Sun, they are seen on the western horizon after the sunset and become invisible in the west. After some time, their longitudes become lesser than the Sun due to their retrograde motion. In such a case, they can be seen in the east before the sunrise.

The apparent diameters of the planets as seen from the Earth are:

Mars	9".4
Mercury	6".6
Jupiter	190".4
Venus	16".6
Saturn	158".0

The planets become combust when they are at a longitudinal distance as given on next page.

	Direct	Retrograde
Moon	12°	—
Mars	17°	—
Mercury	14°	12°
Jupiter	11°	—
Venus	10°	8°
Saturn	15°	—

From the above table, it is seen that there is nothing in the retrograde column against the Moon, Mars Jupiter and Saturn. Since the Moon is never retrograde, the question of its being in the retrograde column does not rise.

The outer planets (Saturn, Jupiter and Mars) are combust only when they are in conjunction with the Sun and not in opposition. When they are near the Sun i.e. near conjunction, they become combust. In case of opposition, their longitudinal distance is nearly 180°. The outer planets become retrograde, when they are nearer to opposition than conjunction.

Now, consider the tables of apparent diameters and their distance of combustion.

Though Saturn is more distant from the Sun than the Jupiter's distance from the Sun yet the degree of combustion of Jupiter is 11° while that of Saturn is 15°. The reason is that the diameter of disc of Jupiter is bigger than that of Saturn. So, Jupiter is visible to naked eye when it is nearer to the Sun.

The longitudinal distance of combustion of Venus is lesser than that of Mercury in spite of its distance being more than the later. This is so on account of

bigger diameter of the disc of Venus.

It might have also been noticed that in the case of Venus and Mercury the longitudinal distance of their combustion is more while they are direct than when retrograde. At the time of direct motion, the Sun is in between the planet and the Earth. By this it can be inferred that at the time of superior conjunction the planet is farthest from the Earth and at the time of inferior conjunction it is nearest to it. The disc of the planet will appear bigger when it is nearer and shorter when it is farther.

Latitudes of the planets have not been considered for the combustion of planets but only longitudinal distances have been accounted for. By not considering latitudes sometimes there is a difference of many days between the theoretical combustion of planets and the actual combustion which is by observation in the sky as shown in between the figure.

Let N W S E be the ecliptic. Let O be the centre of the earth or, say, observer.

S be the Sun.

P be the planet position as per the longitude.

P_1 is the actual position of the planet.

Now, a fast-moving planet is behind the Sun by a certain

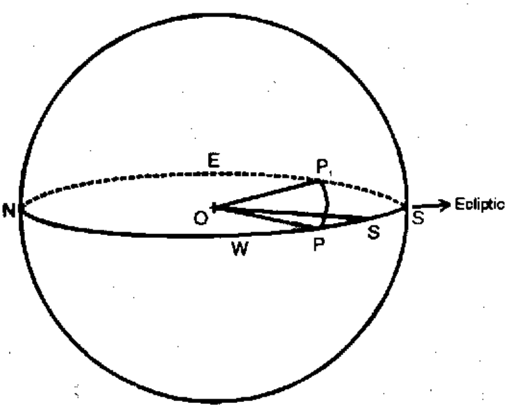


Figure 24

longitudinal distance. The $\angle SOP$ is that longitudinal distance, at the time when the combustion starts, the planet is actually at P_1. The distance P_1S i.e. $\angle P_1OS$ is more than $\angle POS$. Hence the planet will actually be combust when its actual angular distance from the Sun will be equal to $\angle POS$. The planet will have to move nearer to the Sun i.e. it will take some more days before it becomes combust. For this, the method of correction has been given in the Surya siddhanta.

Test Yourself

Q 1. Define Mahayugas. What are its divisions and their lengths of time?

Q 2. Write short notes on:

(a) Surya siddhanta

(b) Varaha siddhanta

(c) Arya siddhanta

Q 3. What is the difference between the approach of Indian astronomy and that of Western astronomy?

Q 4. Write Short notes on;

(a) Galileo

(b) Sir Issac Newton

(c) Nicholas Copernicus

(d) Sir William Herschal

(e) John Couch Adams

Q 5. When is the altitude of a planet greatest during a day and why?

Q 6. Name any four great circles on the celestial shpere. Give their importance.

Q 7. What is the relationship between planets and names of weekdays?

Q 8. Do the planets move retrograde? Give reason in support of your answer.

Q 9. Which is the most luminous planet (excluding luminaries Sun and Moon)?

Q 10. What is the highest latitude north or south at which it is possible to see the Sun in the Zenith at noon.

Q 11. Why the Sun is never seen in Zenith at Delhi when it can be seen at Madras? Give reasons to justify your answer.

Q 12. Which planets cannot be seen by naked eye and why?

Q 13. How does the solar eclipse take place? What is the maximum limit of its totality? What are the various kinds of solar eclipses?

Q 14. Under what conditions does lunar eclipse take place? What is the maximum limit of its totality?

Q 15. What is the role of Rahu and Ketu in the eclipses? Can an clipse take place when the Moon is not near Rahu or Ketu?

Q 16. Write short notes on:

(a) Local time

(b) Indian Standard Time

(c) Zonal Standard Time

Q 17. What are the different units for measuring distances of stars?

Q 18. What is a Luni-Solar year? How is it related

to Lunar year and Solar year?

Q 19. What is *Panchanga*? How the tithi and Karana are calculated? Find out tithi and Karana at 2.30 p.m. on December 12, 2000.

Q 20. How the nakshatras and yogas are found out? What nakshatra and yoga will be on December 28, 2000 at 5.30 p.m.?

Q 21. Sometimes a tithi is missed and on another occasion one tithi is named for two days. Explain the reason and explain with the help of an example.

Q 22. Find out the day on February 19, 2000 by the calendar method. Explain it with the help of an example.

INDEX

Errata

Page 62 Twelfth line read 'foci' instead of 'oci'.

Page 80 Figure 16 delete '$D_2E_2E_3$'

Page 80 Tenth line from bottom read 'E_1SM_3' for 'SM_3E_3'

Page 80 Eleventh line from bottom read 'ESM_2' for 'SM_2E_2'

Page 80 Third line from bottom read 'E' for 'E_2' and 'E_1' for 'E_3'

Page 81 Seventh line read 'J' and 'J_1' for 'J_2' and 'J_3' respectively.

Page 129 Twelfth line delete ',' after 'Mercury' and bring 'and' before 'Moon'.

Page 129 Eeventh line from bottom delete words 'such' and 'a'.

Page 129 Tenth line from bottom put ';' after Sun instead of '.'

Page 130 Twelfth line insert 'moves' after 'zodiac'.

Table of Planetary Movement

Names of planets	Mean distance from the Sun (in miles)	Mean orbital velocity in miles per second	Albedo	Sidereal period in Earth days	Synodic period in Earth days	Period of rotat-ion in Earth days	Equato-rial diame-ter in miles	Eccent-ricity of the orbit	Orbital inclina-tion to Ecliptic	Mass (Earth = 1)	Density (Water = 1)	Surface Gravity (Earth = 1)	Volume (Earth = 1)	Escape velocity miles per second	Maxi-mum Magnit-ude	Inclina-tion of Equator to orbit	Arcs which they retro-grade	Number of Satellite
Mercury	36,000,000	29.7	0.06	88	115.9	58.65	3,033	0.206	7°0'	0.055	5.5	0.38	0.055	2.6	(–) 1.9	—	12°	0
Venus	67,200,000	21.7	0.76	224.7	583.9	243.16	7,523	0.007	3°24'	0.815	5.25	0.90	0.86	6.4	(–) 4.4	178°	16°	0
						H : M : S												
Earth	92,957,000	18.5	0.36	365.3	—	23:56:04	7,926	0.017	—	1.0	5.52	1	1	6.94	—	23°27'	—	1
Mars	141,500,000	15.0	0.16	687	779.9	24:37:23	4,218	0.093	1°51'	0.107	3.94	0.38	0.15	3.2	(–) 2.8	23°59'	18°	2
Jupiter	483,300,000	8.1	0.43	11.9 yrs	398.9	09:50:30	88,378	0.048	1°18'	318	1.33	2.64	1310	37.1	(–) 2.6	3°5'	9°	16
Saturn	886,100,000	6.0	0.61	29.5 yrs	378.1	10:39:00	74,145	0.056	2°29'	95	0.71	1.16	744	22	(–) 0.3	26°44'	6°	20
Uranus	1,783,000,000	4.2	0.35	84.0 yrs	369.7	17:00:00	32,190	0.047	0°46'	14.6	1.7	1.17	67	13.9	3.6	98°	4°	5
Neptune	2,793,000,000	3.4	0.35	164.8 yrs	367.5	17:57:00	30,760	0.009	1°46'	17.2	1.8	1.2	57	15.1	7.7	28°48'	3°	2
Pluto	3,667,000,000	2.9	0.47	247.7 yrs	366.7	6days 9hrs 17min	1,800	0.248	17°10'	—	—	below 0.1	—	—	14	—	—	1
Sun	—	135	—	—		25.4 days	8,65,000	—	—	330,000	1.41	28	1,300,000	384	—	—	—	—
Moon	239,000 from the Earth	1.02 km/sec	7%	27.321	29.53	27.3 days	2,160	0.055	5°15'	1/81	3.34	0.16	—	1.5	(–) 12.7	—	—	—

Albedo is the reflecting power of a planet in the ratio of the amount of light reflected from the body to the amount of light, which falls upon it from an outside source.

Magnitude is a term for brightness. The greater the magnitude, the lesser is the brightness. Where the figure is in minus it means that planet is brighter than the planet having positive figure.